PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 09 October 2000 (09.10.00)	
International application No. PCT/FI00/00166	**Applicant's or agent's file reference** VAL 188 PCT
International filing date (day/month/year) 02 March 2000 (02.03.00)	**Priority date** (day/month/year) 04 March 1999 (04.03.99)
Applicant MÄENPÄÄ, Tapio et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

05 September 2000 (05.09.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

Charlotte ENGER

Telephone No.: (41-22) 338.83.38

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00166

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: D21H 23/78, D21H 25/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F26B, D21F, D21H, D21G, G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5715158 A (SHIH-CHIN CHEN), 3 February 1998 (03.02.98), column 5, line 53 - column 7, line 64	1-13
A	DE 3741128 A1 (VALMET OY), 30 June 1988 (30.06.88), abstract	1-13
A	DE 3901378 A1 (VALMET PAPER MACHINERY INC.), 10 August 1989 (10.08.89)	1-13
A	US 5377428 A (RALPH C. CLARK), 3 January 1995 (03.01.95), abstract	1-13

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 June 2000	14 -06- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Barbro Nilsson/Els Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00166

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9841805 A1 (VITS-MASCHINENBAU GMBH), 24 Sept 1998 (24.09.98), abstract -- --------	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/FI 00/00166

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5715158 A	03/02/98	NONE	
DE 3741128 A1	30/06/88	FI 80100 B,C	29/12/89
		FI 865199 A	19/06/88
		SE 8704992 A	19/06/88
DE 3901378 A1	10/08/89	FI 81627 B,C	31/07/90
		FI 880459 A	03/08/89
		JP 1229891 A	13/09/89
		SE 8900286 A	27/01/89
US 5377428 A	03/01/95	CA 2117576 A,C	15/03/95
		EP 0643165 A	15/03/95
WO 9841805 A1	24/09/98	DE 19710549 A,C	17/09/98

PATENT COOPERATION TREA

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

SEPPO LAINE OY
Itämerenkatu 3 B
FIN-00180 Helsinki
FINLANDE

Date of mailing (day/month/year)
30 May 2001 (30.05.01)

Applicant's or agent's file reference
VAL 188 PCT

IMPORTANT NOTIFICATION

International application No.
PCT/FI00/00166

International filing date (day/month/year)
02 March 2000 (02.03.00)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address
VALMET CORPORATION
Fabianinkatu 9 A
FIN-00130 Helsinki
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: 020 484 100
Facsimile No.: 020 484 101
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [ ] the address [ ] the nationality [ ] the residence

Name and Address
METSO PAPER, INC.
Fabianinkatu 9 A
FIN-00130 Helsinki
Finland

State of Nationality: FI
State of Residence: FI
Telephone No.: 020 484 100
Facsimile No.: 020 484 101
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

Authorized officer
A. Karkachi
Telephone No.: (41-22) 338.83.38

004054287

The demand must be filed directly with the competent International Preliminary Examining Authority, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ SE

PCT 09/914657 CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:
The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

For International Preliminary Examining Authority use only

Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION

Applicant's or agent's file reference: VAL 188 PCT

International application No.	International filing date *(day/month/year)*	(Earliest) Priority date *(day/month/year)*
PCT/FI00/00166	2 March 2000 (2.3.2000)	4 March 1999 (4.3.99)

Title of invention: Method for controlling the machine-direction moisture profile of a web on a coater

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

VALMET CORPORATION
Fabianinkatu 9 A
FIN-00130 Helsinki
Finland

Telephone No.:

Facsimile No.:

Teleprinter No.:

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
Finland	Finland

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

MÄENPÄÄ, Tapio
Kaukopääntie 6
FIN-00950 Helsinki
Finland

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
Finland	Finland

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

SUOMI, Eero
Ruutikellarintie 13 A
FIN-13210 Hämeenlinna
Finland

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
Finland	Finland

[X] Further applicants are indicated on a continuation sheet.

Sheet No. 2.

International application No.
PCT/FI00/00166

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

NISSINEN, Vilho
Onkimaantie 195
FIN-04660 Numminen
Finland

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
Finland	Finland

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

☐ Further applicants are indicated on another continuation sheet.

International application No.
PCT/FI00/00166

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is [X] agent [ ] common representative

and [X] has been appointed earlier and represents the applicant(s) also for international preliminary examination.

[ ] is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

[ ] is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

SEPPO LAINE OY
Itämerenkatu 3 B
FIN-00180 Helsinki
Finland

Telephone No.: +358-9-68 59 560

Facsimile No.: +358-9-68 595 610

Teleprinter No.:

[ ] **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special addr ess to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination **to start on the basis of:**

[X] the international application as originally filed

the description [ ] as originally filed
[ ] as amended under Article 34

the claims [ ] as originally filed
[ ] as amended under Article 19 (together with any accompanying statement)
[ ] as amended under Article 34

the drawings [ ] as originally filed
[ ] as amended under Article 34

2. [ ] The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. [ ] The applicant wishes the start of the international preliminary examination **to be postponed** until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69.1(d)). *(This check-box may be marked only where the time limit under Article 19 has not yet expired.)*

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

[ ] which is the language in which the international application was filed.

[ ] which is the language of a translation furnished for the purposes of international search.

[X] which is the language of publication of the international application.

[ ] which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The applicant hereby **elects all eligible States** *(that is, all States which have been designated and which are bound by Chapter II of the PCT)*

excluding the following States which the applicant wishes **not to elect:**

Sheet No. 4

International application No.
PCT/FI00/00166

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:			For International Preliminary Examining Authority use only: received	not received
1. translation of international application	:	sheets	☐	☐
2. amendments under Article 34	:	sheets	☐	☐
3. copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
4. copy (or, where required, translation) of statement under Article 19	:	sheets	☐	☐
5. letter	:	sheets	☐	☐
6. other *(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. [X] fee calculation sheet
2. [ ] separate signed power of attorney
3. [ ] copy of general power of attorney; reference number, if any:
4. [ ] statement explaining lack of signature
5. [ ] nucleotide and or amino acid sequence listing in computer readable form
6. [ ] other *(specify)*:

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).

For the Applicants

Seppo Laine Oy

Simo Hovi

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:
2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):
3. [ ] The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply. [ ] The applicant has been informed accordingly.
4. [ ] The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80.5.
5. [ ] Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

1762

09/914657 1700

RECEIVED MAR 04 2002 TC 1700

REC'D 03 JUL 2001 WIPO PCT

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

14

Applicant's or agent's file reference VAL 188 PCT	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/FI00/00166	International filing date *(day/month/year)* 02.03.2000	Priority date *(day/month/year)* 04.03.1999
International Patent Classification (IPC) or national classification and IPC7 D 21 H 23/78 D 21 H 25/06		
Applicant METSO PAPER INC. et al		

RECEIVED APR 17 2002 TC 1700

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of _____ sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
05.09.2000	25.06.2001
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Telex 17978 PATOREG-S Facsimile No. 08-667 72 88	Authorized officer Barbro Nilsson/ELY Telephone No. 08-782 25 00

Form PCT/IPEA/409 (cover sheet) (January 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/PCT/FI00/00166

I. Basis of the report

1. With regard to the **elements** of the international application:*

☒ the international application as originally filed

☐ the description:
pages _____, as originally filed
pages _____, filed with the demand
pages _____, filed with the letter of _____

☐ the claims:
pages _____, as originally filed
pages _____, as amended (together with any statement) under article 19
pages _____, filed with the demand
pages _____, filed with the letter of _____

☐ the drawings:
pages _____, as originally filed
pages _____, filed with the demand
pages _____, filed with the letter of _____

☐ the sequence listing part of the description:
pages _____, as originally filed
pages _____, filed with the demand
pages _____, filed with the letter of _____

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language English which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

☒ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages _____

☐ the claims, Nos. _____

☐ the drawings, sheet/fig _____

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2 (c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item I and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/PCT/FI00/00166

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-13	YES
	Claims		NO
Inventive step (IS)	Claims	1-13	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-13	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

The invention relates to a method for controlling the drying effect of equipment used in making coated web of paper or board.

The object of the invention is to provide a method for controlling the machine direction moisture profile in that the moisture of the paper will be kept at a constant level during the run. This is achieved by a method comprising the following steps:

- A specific evaporation rate submodel is compiled for each one of those portions of the coater section in which moisture is evaporated. This is suited to compute the amount of liquid removed within said portion.
- Determining the needed overall evaporation effect.
- The submodels are chained into a composite evaporation rate model.
- The needed overall evaporation effect is divided between the dryers of the equipment with the help of the composite model.
- The model is used to determine new control variable set values to be issued to said dryers. This will form a complete model for the evaporation process of the web.

The most relevant document cited in the International Search Report:

D1 US 5715158 A

.../...

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: V.

D1 discloses a method and an apparatus for controlling an extended process and, more particularly, a process in which a paper web is processed in a papermaking machine. The total control system (130) is made up of a plurality of control loops. Each control loop (150A-150X) processes signals relating to a portion of the extended process with which the control loop is associated (refer to column 6, lines 40-55). Sensors are spaced along an extended process from its beginning end to its finishing end. Each sensor is associated with a parallel inferential control loop and generates an actual measurement signal for a portion of the process. The loop control signal, corresponding to a portion of the process, is summed to generate a total control signal.

The claimed invention differs from the method in D1 in that D1 does not describe a specific evaporation rate submodel for the different parts of the apparatus in which moisture is evaporated from the web. Furthermore, it does not chain these submodels into a composite overall model for the whole drying process and divide the needed evaporation effect between the dryers into new control set values. D1 does not mention a way of connecting different apparatus within the control loops for a portion of the process. Thus, the claimed invention is novel. Moreover, in view of the knowledge in D1 it is not considered obvious to a person skilled in the art to control the drying of a coated web in the manner of the present invention.

Therefore, in accordance with the arguments stated above, the claimed invention is novel, considered to involve an inventive step and have industrial applicability.

RECORD COPY

PCT REQUEST

09/914657

09/914657

VAL 188 PCT

Original (for **SUBMISSION**) - printed on 02.03.2000 09:44:53 AM

0	**For receiving Office use only**	
0-1	International Application No.	PCT/FI00/00166
0-2	International Filing Date	02 MAR 2000 (02.03.00)
0-3	Name of receiving Office and "PCT International Application"	The Finnish Patent Office PCT International Application

0-4	**Form - PCT/RO/101 PCT Request**	
0-4-1	Prepared using	PCT-EASY Version 2.90 (updated 15.12.1999)
0-5	**Petition** The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	**Receiving Office (specified by the applicant)**	National Board of Patents and Registration (Finland) (RO/FI)
0-7	**Applicant's or agent's file reference**	VAL 188 PCT
I	**Title of invention**	METHOD FOR CONTROLLING THE MOISTURE OF A WEB IN MACHINE DIRECTION ON A COATING MACHINE
II	**Applicant**	
II-1	This person is:	applicant only
II-2	Applicant for	all designated States except US
II-4	Name	VALMET CORPORATION
II-5	Address:	Fabianinkatu 9 A FIN-00130 Helsinki Finland
II-6	State of nationality	FI
II-7	State of residence	FI
II-8	Telephone No.	020 484 100
II-9	Facsimile No.	020 484 101
III-1	**Applicant and/or inventor**	
III-1-1	This person is:	applicant and inventor
III-1-2	Applicant for	US only
III-1-4	Name (LAST, First)	MÄENPÄÄ, Tapio
III-1-5	Address:	Kaukopääntie 6 FIN-00950 Helsinki Finland
III-1-6	State of nationality	FI
III-1-7	State of residence	FI

PCT REQUEST

VAL 188 PCT

Original (for **SUBMISSION**) - printed on 02.03.2000 09:44:53 AM

III-2	**Applicant and/or inv nt r**	
III-2-1	This person is:	applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	SUOMI, Eero
III-2-5	Address:	Ruutikellarintie 13 A FIN-13210 Hämeenlinna Finland
III-2-6	State of nationality	FI
III-2-7	State of residence	FI
III-3	**Applicant and/or inventor**	
III-3-1	This person is:	applicant and inventor
III-3-2	Applicant for	US only
III-3-4	Name (LAST, First)	NISSINEN, Vilho
III-3-5	Address:	Onkimaantie 195 FIN-04660 Numminen Finland
III-3-6	State of nationality	FI
III-3-7	State of residence	FI
IV-1	**Agent or common representative; or address for correspondence** The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
IV-1-1	Name	SEPPO LAINE OY
IV-1-2	Address:	Itämerenkatu 3 B FIN-00180 Helsinki Finland
IV-1-3	Telephone No.	+358-9-68 59 560
IV-1-4	Facsimile No.	+358-9-68 595 610
IV-1-5	e-mail	seppo.laine@selpat.fi

PCT REQUEST

VAL 188 PCT

Original (for **SUBMISSION**) - printed on 02.03.2000 09:44:53 AM

V	**D signati n of Stat s**	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	**AP: GH GM KE LS MW SD SL SZ TZ UG ZW and any other State which is a Contracting State of the Harare Protocol and of the PCT** **EA: AM AZ BY KG KZ MD RU TJ TM and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT** **EP: AT BE CH&LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE and any other State which is a Contracting State of the European Patent Convention and of the PCT** **OA: BF BJ CF CG CI CM GA GN GW ML MR NE SN TD TG and any other State which is a member State of OAPI and a Contracting State of the PCT**
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	**AE AL AM AT AU AZ BA BB BG BR BY CA CH&LI CN CR CU CZ DE DK DM EE ES FI GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX NO NZ PL PT RO RU SD SE SG SI SK SL TJ TM TR TT TZ UA UG US UZ VN YU ZA ZW**
V-5	**Precautionary Designation Statement** In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.	
V-6	**Exclusion(s) from precautionary designations**	**NONE**
VI-1	**Priority claim of earlier national application**	
VI-1-1	Filing date	**04 March 1999 (04.03.1999)**
VI-1-2	Number	**990474**
VI-1-3	Country	**FI**
VI-2	**Priority document request** The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	**VI-1**
VII-1	**Internati nal Searching Authority Chosen**	**Swedish Patent Office (ISA/SE)**

PCT REQUEST

VAL 188 PCT

Original (for **SUBMISSION**) - printed on 02.03.2000 09:44:53 AM

VIII	Check list	number of sheets	electronic file(s) attached
VIII-1	Request	4	-
VIII-2	Description	15	-
VIII-3	Claims	4	-
VIII-4	Abstract	1	val188pct.txt
VIII-5	Drawings	5	-
VIII-7	TOTAL	29	
	Accompanying items	paper document(s) attached	electronic file(s) attached
VIII-8	Fee calculation sheet	✓	-
VIII-16	PCT-EASY diskette	-	diskette
VIII-17	Other (specified):	Copy of official action	-
VIII-18	**Figure of the drawings which should accompany the abstract**	1	
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IX-1	**Signature of applicant or agent**		
IX-1-1	Name	SEPPO LAINE OY	
IX-1-2	Name of signatory	Simo Hovi	

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MENETELMÄ KONESUUNTAISEN RATAKOSTEUDEN SÄÄTÄMISEKSI PÄÄLLYSTYSKONEELLA

Tämän keksinnön kohteena on patenttivaatimuksen 1 johdannon mukainen menetelmä paperin tai vastaavan päällystetyn ratamateriaalin kuten kartongin kuivatukseen käytettävä ohjaus- ja säätöstrategia päällystyskoneissa, joissa päällystettävä rata kulkee yhden tai useampia päällystysasemia sekä kuivaimia käsittävän päällystyskoneen lävitse.

Päällystettyä paperia tai kartonkia valmistettaessa sen pinnalle levitetään päällysteaineita veteen sekoitettuna. Päällysteseoksen levittämisen ja tasoittamisen jälkeen radan pinnalla oleva päällystemassa ja pohjamateriaalirata täytyy kuivata riittävän kuivaksi loppukäyttöä tai jatkokäsittelyä varten. Päällystettyjä paperilaatuja valmistettaessa suurin osa käytettävästä energiasta kuluukin radan kuivattamiseen jälkikäsittelyn eri vaiheissa, joten kuivatuksen energiakäytön hallinta on erityisen tärkeää tuotannon kannattavuuden kannalta. Oikealla kuivatustavalla on vaikutusta myös valmistettavan paperin laatuun. Koneensuuntaisen kosteuden hallinta, eli valmistettavan paperin kosteuden pitäminen tasaisesti samansuuruisena on sekin erittäin tärkeää valmistettavan paperin laadun kannalta. Paperin kosteus vaikuttaa erityisesti kalanteroitavuuteen ja painettavuuteen. Koska nykyisin käytetään on-line kalanterointia, jossa päällystetty rata menee suoraan kalanterille, radan kosteus ei ehdi tasaantua ennen kalanterointia samalla tavoin kuin off-line kalanteroinnissa, jolloin päällystettyä rataa säilytettiin ennen kalanterointia tampuurirullalla. Vastaavasti paperin kuljetusketju paperitehtaasta painoihin ja muille käyttäjille on nopeutunut, joten

kalanteroimattomankaan paperin kosteus ei ehdi välttämättä tasaantua ja laskea riittävän alhaiselle tasolle ennen painatusta. Radan kosteus vaikuttaa päällystettäessä veden imeytymiseen rataan päällystettä levitettäessä ja siten päällysteen kuiva-ainepitoisuuden muuttumiseen päällystyksen jälkeen. Kuiva-ainepitoisuuden muuttuminen vaikuttaa moniin seikkoihin päällystystapahtumassa, joten radan kosteuden pitäminen päällystyksen ja kuivatuksen aikana tarkasti oikeissa rajoissa on tärkeää tasaisen ja oikeanlaisen valmistustuloksen kannalta.

Tavallisesti päällystettyä rataa kuivataan heti päällystyksen jälkeen kosketuksettomilla kuivaimilla, minkä jälkeen voidaan käyttää tarvittaessa sylinterikuivaimia tai muita kosketuksellisia kuivaimia. Radan kosteutta mitataan useissa pisteissä päällystyskoneen pituudella ja kunkin kuivaimen kuivatustehoa säädetään mittaustuloksen perusteella siten, että mittauspisteessä saadaan oikea kosteus koneen poikittaissuunnassa ja tietyissä rajoissa ajon aikana pysyvä kosteusarvo, eli saadaan koneensuuntainen kosteus pysymään asetusarvossa. Kuivatusteho asetetaan koeajojen ja kokemusperäisten tietojen perusteella sopivaan perusasetukseen ja kuivainten tehoja säädetään ajon aikana mittaustulosten perusteella automaattisesti tai käsin. Tavallisesti yksi kuivain tai kuivainryhmä toimii loppukosteuden säätimenä, jonka tehoa muutetaan takaisinkytketyn mittauksen avulla. Muut kuivaimet toimivat tällöin käsisäätöisesti. Tällainen säätötapa on hyvin hidas ja kuivainten toimintahitauden huomioon ottaminen on vaikeaa, jos kuivaintehoja halutaan muuttaa nopeasti. Radan lämpötila ennen päällystysasemaa on pidettävä riittävän alhaisena, jotta levitettävä päällyste ei flokkaantuisi. Tämän takia kuivatustehon hallinta erityisesti kuivatuksen loppuosalla ennen seuraa-

vaa päällystysvaihetta on tärkeää. Ratalämpötila vaikuttaa myös päällystettävän radan laatuun.

Erityisesti ajo-olosuhteiden muuttuessa tai konetta käynnistettäessä eli niin sanotun ylösajon aikana oikeiden kuivaintehojen nostaminen ja asettaminen kohdalleen vaatii hyvää koneen käyttäjien ammattitaitoa. Päällystyskoneen kuivaintehojen saaminen ylösajossa tai ajo-olosuhteiden muututtua prosessin kannalta edulliseen tasapainotilaan vaatii aikaa ja tällöin tuotettava paperi tai kartonki ei täytä laatuvaatimuksia ja on siten ajettava pulpperiin. Koneen tehokkuuden kannalta olisikin edullista saada ylösajoajat ja muutosajat mahdollisimman lyhyiksi. Edellä kuvatulla menetelmällä on myös vaikeaa optimoida käytettävän kuivatusenergian määrää, koska jokaista kuivainta ohjataan erikseen eikä niiden keskinäisiä tehosuhteita voida helposti muuttaa. Yhden tai useamman kuivaimen vaurioituminen on vaikeaa kompensoida, koska prosessi on suunniteltu toimimaan kaikkien kuivainten ollessa toiminnassa.

Tämän keksinnön tarkoituksena on saada aikaan menetelmä, jonka avulla päällystettävän radan koneensuuntaista kosteutta voidaan säätää optimoidusti koko päällystys- ja kuivatustapahtuman kosteudenmuutokset huomioon ottaen. Käytännössä tämä tarkoittaa päällystyskoneen kaikkien kuivainten integroitua säätämistä hallitun ja energiankulutuksen sekä valmistuslaadun kannalta optimaalisen lopputuloksen saavuttamiseksi.

Keksintö perustuu siihen, että jokaiselle radan kuivumiseen vaikuttavalle prosessin osalle ja laitteelle muodostetaan matemaattinen ominaishaihdutusta kuvaava malli ja yksittäisten mallien avulla muodostetaan malleja ketjuttamalla

kokonaisprosessin malli, jonka avulla hallitaan prosessin kuivatustapahtumaa siten, että yksittäisiä laitteita ohjataan prosessin osana.

Täsmällisemmin sanottuna keksinnön mukaiselle menetelmälle on tunnusomaista se, mitä on esitetty patenttivaatimuksen 1 tunnusmerkkiosassa.

Keksinnön avulla saavutetaan huomattavia etuja.

Keksinnön mukaisen mallin avulla voidaan laskea suoraan jokaisen kuivaimen jälkeinen lähtökosteus, kun kuivaimen ominaishaihdutus ja radan tulokosteus tiedetään. Kun mallit ketjutetaan, voidaan laskea kosteus eri paikoissa päällystyskonetta ja tietenkin tärkeimpänä radan loppukosteus. Mallin avulla kuivainten tehoja voidaan säätää niiden ominaisuuksien mukaan siten, että eri tyyppisten kuivainten ominaisuudet tulevat parhaiten huomioiduksi. Koska infrapunakuivaimet toimivat nopeasti, niitä voidaan käyttää esimerkiksi ylösajossa kokonaiskuivaintehon säätöön ja muiden kuivainten tehot voidaan nostaa siten helpommin normaalin ajon aikana tarvittavaan tehoon ottamalla huomioon kuivaimen hitaus malliin sijoitettujen viivetekijöiden avulla. Viivetekijöiden avulla voidaan hallita todellisia prosessin viiveitä.

Koska keksinnön mukaisesti hallitaan koko prosessia, kuivainten tehot voidaan jakaa halutulla halutulla tavalla ja erityisesti jonkin kuivaimen vaurioiduttua sen kuivatusteho voidaan jakaa muille kuivaimille eikä päällystyskoneen toimintaa tarvitse keskeyttää korjauksen ajaksi. Samoin koska radan alkukosteus ja radalle päällysteen mukana tuotu vesimäärä tiedetään, mallin avulla voidaan laskea estimaatti

radan kosteudelle prosessin eri osissa ja erityisesti ennen kiinnirullausta. Mallin avulla loppukosteus voidaan laskea niin tarkasti, että jopa kosteusmittareiden vaurioiduttua valmistusta voidaan jatkaa mallin ohjaamana.

Kaiken kaikkiaan keksinnön avulla saadaan aikaan nopeampi ja tarkempi säätö kuin käsisäädön ja yksittäisten kuivainten takaisinkytketyn säädön avulla.

Keksintöä selitetään seuraavassa tarkemmin oheisten piirustusten avulla.

Kuvio 1 esittää päällystyskonetta tai sen osaa, jossa on yksi päällystysasema ja kuivaimia.

Kuvio 2 esittää päällystyskonetta tai sen osaa, jossa on kaksi päällystysasema ja niillä molemmilla omat kuivaimensa.

Kuvio 3 on kaaviokuva tilanteesta, jossa päällystyskoneen radan nopeus muuttuu.

Kuvio 4 on kaviokuva tilanteesta, jossa kuivatustehoa säädetään nopeuden muutoksen mukaisesti.

Kuvio 5 on lohkokaavio menetelmän toiminnasta.

Kuviossa 1 on esitetty kaaviokuvana yksi päällystysasema 1, siihen liittyvät kuivaimet 2 - 6 sekä lohkokaaviona kuivainten 2 - 6 tehon säätöön liittyvät toimenpiteet. Radan 8 kulkusuunnassa katsottuna on ensimmäiseksi päällystysasema 1, jolla ainakin radan toiselle puolelle levitetään pääl-

lystettä tai muuta käsittelyainetta kuten pintaliimaa. Päällystysaseman tyyppi ei vaikuta keksinnön soveltamiseen, joten se voi olla mikä tahansa sopiva laite, esimerkiksi lyhytviipymäpäällystin, filminsiirtopuristin, teräpäällystysasema tai spraypäällystin. Päällystysasemalla voidaan päällystää vain radan 8 toinen puoli, mikä on tavallisinta, tai molemmat puolet. Kuivainten 2 - 6 rakenne muuttuu tietenkin sen mukaan, käytetäänkö kaksipuolista tai yksipuolista päällystystä samalla asemalla, mutta kaikkien kuivainten toiminta voidaan mallintaa keksinnön mukaisesti.

Päällystysaseman jälkeen seuraa ensin infrapunakuivain 2, sitten kolme ilmakuivainta 3 - 5 ja lopuksi useista kuivainsylintereistä 7 koostuva kuivainsylinteriryhmä 6. Kuivainsylinteriryhmällä 6 rata 8 kuivataan lopulliseen kosteuspitoisuuteen ja rata 8 johdetaan kosteusmittarin 9 kautta kiinnirullaimelle 10.

Prosessia ohjataan tietokoneen avulla. Fyysisesti ohjaustietokone voi olla osa päällystyskoneen ohjaustietokoneen ohjelmiston osa, yksi erillinen kosteuden säätöä varten varattu tietokone tai prosessori tai fyysisesti eri paikkoihin jaettu ohjelmisto ja tietokanta. Ohjausjärjestelmä sisältää kunkin kuivaimen haihdutusmallin ja näistä koostuvan kokonaishaihdutusmallin. Lisäksi ohjausjärjestelmän tietokantaan 11 kerätään mittaamalla tai suoraan päällystyskoneen ohjausjärjestelmän tiedoista prosessin statustiedot, eli koneen ja mallin hetkellinen tila. Tilatiedot käsittävät muun muassa päällystysaseman tilan, eli päällystemäärän, kuiva-ainepitoisuuden, jne, kuivainten tehot, loppukosteuden kuivainten jälkeen ja kiinnirullaimella 10 mitatun radan nopeuden.

Kuviossa 2 on esitetty järjestelmä, johon kuuluu kaksi päällystysasemaa ja niihin liittyvät kuivaimet. Tässä esimerkissä nämä ovat järjestelmän kaksi viimeistä päällystintä ja järjestelmään voi kuulua useitakin tämänkaltaisia päällystinaseman ja kuivainten muodostamia osajärjestelmiä. Jokaista osajärjestelmää varten voi olla oma haihdutusmallinsa, tai edullisimmin koko päällystyskoneelle muodostetaan yksi malli, jolloin prosessin toimintaa voidaan helpommin ohjata. Erityisesti radan kosteus voi olla ennen sen johtamista seuraavaan päällystysvaiheeseen joissain tapauksissa suurempi kuin radan loppukosteus, jolloin rata kulkee päällystyskoneen läpi keskimäärin kosteampana kuin se tulee kiinnirullaimelle. Tällaisessa tapauksessa kuivatustehoa tarvitaan enemmän viimeisen päällystysaseman jälkeen kuin edellisillä asemilla, mikä on helppo ottaa huomioon keksinnön mukaisen menetelmän avulla siirtämällä seuraavan osan jälkeisen kosteuden laskettu tai mitattu kosteusarvo edellisen osajärjestelmän haihdutustehon laskentaan. Paperikoneelta päällystettäväksi tulevan radan radan kosteus on noin 1,5 - 4% ja käsitellyn radan kosteus 4 - 6%. Radan kosteusarvot eri käsittelyn vaiheessa voivat vaihdella paljonkin ja myös loppu ja alkukosteuden arvot vaihtelevat valmistettavan laadun mukaan. Tarvittaessa radan alkukosteus voidaan laskea mallin antaman ajotilanteen haihdutusmäärän ja ennen kiinnirullausta mitatun loppukosteuden mukaan.

Keksinnön mukaisella menetelmällä pyritään päällystyskoneen konesuuntaisen kosteuden tarkkaan kokonaishallintaan kaikissa tuotantotilanteissa ja siirryttäessä tuotantotilaan, eli ylösajossa sekä nopeusmuutosten ja päällystystapahtuman muutosten aikana. Menetelmällä kyetään hallitsemaan useita päällystyskoneen kuivaimia samanaikaisesti siten, että tavoitekosteus saavutetaan. Keksinnön mukaisen uuden lähesty-

mistavan mukaan muodostetaan kullekin kuivainyksikölle matemaattinen ominaishaihdutusta kuvaava malli, jota hyödynnetään kokonaissäätöstrategiassa laskettaessa kuivainkohtaiset asetusarvot. Muodostettuja ominaishaihdutuslaskentamalleja käytetään ketjutetusti kuvaamaan kokonaisprosessia, minkä lisäksi käytetään tiettyjä prosessimittauksia. Matemaattisten malliyhtälöjen parametrejä voidaan päivittää laji- ja toimintapistekohtaisesti joko off-line- tai on-line -menetelmiä käyttäen. Tällä tavoin saadaan muodostettu laskennallinen malli vastaamaan tarkasti käytettävän päällystyskoneen toimintaa erilaisilla valmistettavilla laaduilla ja eri prosessiolosuhteissa.

Menetelmää voidaan soveltaa sekä ns. off-machine että on-machine päällystyskoneisiin, sen avulla voidaan toteuttaa normaalin tuotantotilanteen vaatimat kuivainten ohjaukset että ohjaukset tilanteissa, jolloin ollaan siirtymässä tuotantotilaan. Normaalilla tuotantotilanteella tarkoitetaan tilannetta, jolloin konenopeudessa ei tapahdu muutoksia tai konenopeuden muutokset eivät vaikuta laatuun. Konenopeuden muutostilanteet ja koneen ylösajo edustavat muutos- ja siirtotiloja/-tilanteita. Menetelmässä käytetään laatumittausjärjestelmästä tai muualta, kuten päällystyskoneen ohjausjärjestelmästä saatavia saatavia ratakosteuden, neliöpainon, päällystemäärän, päällysteen kuiva-ainepitoisuuden ja ratalämpötilan mittausarvoja. Laatumittausjärjestelmän mitta-anturit voivat olla joko kunkin päällysteasemayksikön viimeisimmän kuivaimen jälkeen ja ennen kiinnirullainta vastaten täydellistä mittauskonseptia tai osa ns. välikosteusmittauksista voi puuttua, jolloin käytetään hyväksi kuivatusmallin laskemia ratakosteuden estimaatteja, jotka vastaavat tarkasti todellista tilannetta erityisesti silloin, kun malliyhtälöiden parametrit on päivitetty.

Tarkasteltavassa menetelmässä lasketaan matemaattisiin malleihin perustuen kunkin kuivaimen tai kuivumistapahtumaan vaikuttavan prosessiyksikön ominaishaihdutuskyky esim. ilmoitettuna $kgH_2O/m^2/h$. Laskentaan sisältyvät päällystysasemat, infrapunakuivaimet, leijukuivaimet, sylinterikuivaimet ja muut päällystyskoneella käytettävät kuivaimet sekä kuivaimien väliset vapaat vedot. Vapaat vedotkin on tärkeä mallintaa ja ottaa mukaan kokonaismalliin, koska kuivaimilta tulevasta kuumasta radasta haihtuu niiden osalla nestettä.

Päällystysasemalla päällystysteen mukana tuodaan paperin pinnalle tietty ylimäärä vettä, joka kuivaimilla pitää poistaa. Kun radan alkukosteus ja päällystemäärä sekä päällysteen sisältämä vesimäärä tiedetään, voidaan laskea radan nopeuden perusteella tarvittava kokonaishaihdutusteho ja jakaa se eri kuivaimille. Tavoitteena on ajaa kunkin päällystysaseman jälkeinen ns. välikosteus ja tuotteen loppukosteus halutuiksi ohjaamalla päällystyskoneen kuivaimia yhtenäisenä järjestelmänä. Ominaishaihdutuslaskennassa käytetään hyväksi mittaustietoja ratakosteudesta, -lämpötilasta, -nopeudesta ja ympäröivän ilman kosteudesta. Ominaishaihdutusmalleja käyttäen voidaan laskea estimaatti kunkin kuivaimen jälkeiselle ratakosteudelle. Samoin voidaan laskea ratalämpötilan muutos kussakin yksikössä ja yksikön jälkeinen ratalämpötila. Kytkemällä kuivainten ja vapaavetojen matemaattiset malliyhtälöt toisiinsa saadaan kokonaisjärjestelmän ketjutettu malli. Tällöin siis edelliselle kuivaimelle laskettuja ratakosteuden ja ratalämpötilan lähtöarvoja käytetään seuraavalla kuivaimella syöttötietoina eli tulevan radan kosteuden ja lämpötilan arvoina.

Menetelmässä kunkin päällystysyksikön jälkeistä välikosteutta ja tuotteen loppukosteutta kiinnirullaimella säädetään käyttämällä hyväksi päällystyskoneen kuivainten ominaishaihdutuslaskentamalleja. Mallien avulla lasketaan kullekin kuivaimelle sellaiset ohjaus- ja säätösuureiden asetusarvot, jotta halutut väli- ja loppukosteudet saavutetaan. Tämä koskee myös konenopeuden muutostilannetta. Säätö suoritetaan sekä suljettuna että ennakoivana säätönä. Laatumittausjärjestelmästä saatavaa kosteusmittaustietoa käytetään takaisinkytkentään, jolla korjataan päällystyskoneen joko yhden tai useamman kuivaimen asetusarvoja. Ennakoivassa säädössä, jota käytetään konenopeuden muutosten yhteydessä, hyödynnetään ominaishaihdutuslaskentamalleista saatavia konenopeuden lopputilaa vastaavia kuivainten asetusarvojen estimaatteja. Tässä selityksessä ei kuvata itse mallien laatimista, jota varten löytyy matemaattisia työkaluja alan kirjallisuudesta.

Ensimmäiseksi keksinnön mukaisessa menetelmässä on laskettava järjestelmän eri laitteiden ominaishaihdutus. Päällystyskoneen erilaisten kuivainten ominaishaihdutus $kgH_2O/m^2/h$ lasketaan joko automaatiojärjestelmässä tai tähän välittömässä yhteydessä olevassa erillisessä laskentayksikössä. Päällystyskoneen kuivainten laskentamallit käsittävät päällystysasemat, infrapunakuivaimet, leijukuivaimet ja sylinterikuivaimet ja muut päällystyskoneella käytetyt kuivaimet sekä kuivaimien väliset vapaat vedot. Laskentamallit huomioivat kunkin kuivaimen karakteristisen ohjausmuuttujien sekä prosessisuureiden vaikutuksen ominaishaihdutukseen. Tällaisia muuttujia ovat radanopeus, radan tulokosteus ja lämpötila, neliöpaino, päällystemäärä, päällysteen kuiva-ainepitoisuus ja koostumus, ilman kosteus, infrapunakuivaimen teho (kW/m), leijukuivaimen puhallusilman lämpötila ja

puhallusilman virtausnopeus, sylinterikuivainten höyrynpaine ja virtaus. Laskennan tuloksena saadaan kunkin kuivainyksikön ominaishaihdutus, kuivaimesta poistuvan radan kosteuspitoisuus ja radan lämpötila ko. tarkastelupisteessä käytettäessä valittuja ohjausmuuttujia.

Kuivatusmallien karakteristisia parametreja voidaan korjata laatumittaustietojen perusteella esim. paperilaji- ja toimintapistekohtaisesti. Tällä tavoin saadaan malli sovitettua vastaamaan tarkasti todellista toimintatilannetta ja käytettävän päällystyskoneen ominaisuuksia. Tällöin mallin antamaa ratakosteuden estimaattia jossain radan kohdassa, esimerkiksi ennen kiinnirullausta, verrataan mittalaitteiden antamaan todelliseen kosteustietoon. Tämän perusteella muodostetaan mallin virhe, jota käytetään malliparametrien korjauslaskennassa. Korjauslaskenta voidaan tehdä joko offline laskentana automaatiojärjestelmässä tai tähän liitetyssä muussa järjestelmässä tai suoraan on-line laskentana automaatiojärjestelmässä, käyttäen asianmukaisia laskentarutiineja esim. pienimmän neliösumman menetelmää tai vastaavia rekursiivisia algoritmejä. Tällöin kuivaimia ohjataan erillisen strategian mukaisesti siten, että kaikkia muita kuivaimia paitsi sitä, jonka malliyhtälön parametrejä tarkastellaan ajetaan vakioteholla. Parametrien päivityksen aikana ko. kuivaimen ohjauksiin tehdään käytetyn identifiointimenetelmän mukaisesti asianmukaisia muutoksia esim. asetusarvon askelmaisia muutoksia tai kytketään PRBS - signaali (Pseudo-Random-Binary-Signal) asetusarvoihin, jotta tarkasteltavassa järjestelmässä olisi identifiointimenetelmän vaatima riittävä määrä vaihteluita parametrien laskenta-algoritmin konvergoitumiseksi. Paperilaji- ja prosessin toimintapistekohtaiset malliyhtälöjen parametrien arvot voidaan tallentaa erilliseen tietokantaan tai automaa-

tiojärjestelmän lajiresepteihin

Ratakosteuden konesuuntainen säätö tapahtuu keksinnön mukaan seuraavasti. Tarkasteltavassa menetelmässä mallipohjainen kosteussäätäjä muodostaa mitatun ratakosteusarvon ja tavoitekosteusarvon erosta ohjausviestin, jonka laskennassa hyödynnetään yksittäisten kuivainten matemaattisista malleista muodostettua yhdistettyä säätömallia. Laskenta perustuu kuivainten ominaishaihdutustehoon ja vallitseviin prosessiolosuhteisiin. Mallien avulla lasketaan kullekin kuivaimelle sellaiset ohjaus- ja säätösuureiden asetusarvot, jotta halutut väli- ja loppukosteusarvot saavutetaan. Konenopeuden muutostilojen yhteydessä säätöalgoritmi laskee kuivainten tehon muutostarpeen radanopeuden muuttuessa.

Normaalissa tuotantotilanteessa, jolloin radanopeus ei muutu säätö toteutetaan takaisinkytkettynä säätönä, jolloin kosteuden asetusarvon ja mittauksen perusteella muodostetaan tieto kosteuserosta, jonka perusteella säätöalgoritmi tekee käyttäjän määrittämässä laajuudessa tarvittavat muutokset tietokoneen säätämiksi valittujen kuivainten tehoihin. Kaikki kuivaimet ovat valittavissa tietokonesäädölle tai vastaavasti käsisäädölle, mutta keksinnön mukaan ainakin yhden kuivaimen tehoa on voitava säätää tietokoneen avulla tapahtuvan malliohjauksen avulla. Tällöin kuvion 2 mukaisesti joko välikosteusmitta-anturilta 12 tai ennen kiinnirullausta 10 olevalta laatumittausanturilta 9 saadaan ratakosteuden oloarvo, jota säätöohjelma vertaa asetusarvoon. Asetusarvon ja mittauksen kosteuseron perusteella lasketaan vastaava kokonaisvesimäärän (ΔH_2O) muutos, joka tietokonesäädölle valittujen kuivaimien pitää saada aikaan. Mikäli kosteusero on etumerkiltään positiivinen pitää ominaishaihdutusta lisätä. Negatiivisessa tapauksessa pienen-

tää. Kokonaisvesimääräero (ΔH_2O) jaetaan tietokonesäädölle valituille kuivaimille ($i = 1..N$) suhteellisella painokertoimella (0-100 %) painotettuna siten, että painokertoimien summa on kuitenkin 100. Kosteusero, eli tarvittava tehon muutos, voidaan jakaa kuivaimille myös muullakin tavalla painottamalla. Painokertoimet voidaan valita esimerkiksi kuivainten haihdutustehojen suhteessa tai halutun välikosteuden perusteella. Suhteellisessa jaossa kunkin painokertoimen osoittama osuus vesimääräerosta kohdistuu valitulle kuivaimelle. Ominaishaihdutusmalleja käytetään laskettaessa vaadittavat muutokset kunkin kuivaimen ohjausten asetusarvoihin. Uudet asetusarvot välitetään tämän jälkeen yksikkösäädinpiireille, jotka toteuttavat asetusarvojen muutokset.

Kuvion 3 esittää tilannetta, jossa konenopeus muuttuu. Tällöin toteutetaan säätö ennakoivasti. Tehtäessä konenopeudessa muutos pisteestä A pisteeseen C, menetellään seuraavasti. Pisteessä A lasketaan päällystyskoneen kuivaimille pistettä C vastaavat uudet asetusarvot malliyhtälöjen perusteella siten, että huomioiden konenopeuden muutoksesta aiheutuva korjaus asetusarvoihin. Uudet asetusarvot voidaan välittää yksikkösäädinpiireille joko välittömästi konenopeuden muutoksen alkaessa (piste A) tai inkrementeittäin konenopeusmuutoksen aikana kuvion 4 mukaisesti. Tähän valintaan vaikuttavat konenopeuden muutoksen suuruus (ΔL), muutosaika (ΔT) ja valitun kuivaimen tai yksikön dynaaminen käyttäytyminen. Koneen ylösajon aikana menetellään esim. kuvan 3 käyrän oikeanpuoleisen esitystavan mukaisesti. Pisteessä A' lasketaan joko pistettä B' tai pistettä C' vastaavat uudet asetusarvot yksikkösäädinpiireille malliyhtälöjen avulla. Mikäli koneen kiihdytys tehdään välivaiheen B' kautta voidaan tavoitenopeutta C' vastaavat asetusarvot

välittää joko pisteessä A', B' tai inkrementeittäin porrastaen (Kuva 4). Dynamiikaltaan nopeille kuivaimille, kuten infrapunakuivaimille, voidaan asetusarvojen alku- ja loppupisteiden arvojen perusteella laskea haluttu määrä inkrementtipisteitä, jotka aktivoituvat kun konenopeus on saavuttanut ko. asetusarvoa vastaavan nopeuden. Toisaalta mikäli esim. leiju- ja sylinterikuivainten dynamiikan hitaus (aikavakio t) otetaan mukaan, voidaan pistettä C' vastaavat asetusarvot valituille kuivaimille välittää jo pisteessä (A'- t) tai huomioida hitaus inkrementtijaossa. Vaihetta B' käytetään yleisesti esim. päällystysasemien sulkemiseen. Tällöin, riippuen ajasta (ΔT), voidaan laskea myös pistettä B' vastaavat yksikkösäädinpiirien asetusarvot, joita käytetään lähtöarvoina siirryttäessä tilaan C'. Menetelmä kattaa myös tilanteet jolloin konenopeusmuutosten tai ylösajon aikana käytetään laatumittausjärjestelmästä saatavia täyden profiilin mittauksia tai osittaisia profiilimittauksia hyväksi. Osittaisessa profiilimittauksessa laatumittausjärjestelmän mitta-anturi voi olla ns. pistemittauksella (ei traversoi) tai mitta-anturi voi traversoida, eli kulkea radan poikki vain osittain, esim. 0.5 -1.0m leveydeltä. Tällöin aina uuden luotettavan mittaustiedon valmistuttua tehdään korjaus kuivainten asetusarvojen estimaatteihin malliyhtälöjen tai muun korjauslaskennan perusteella.

Kuviossa 5 on esitetty edellä kuvattu säätötapa hieman erityyppisenä kaaviona. Tässä kaaviossa esitetty säätötapa vastaa kuvioiden 1 ja 2 mukaista säätöä. Kuvion vasemmassa laidassa on kosteuden eroarvon määrittäminen. Ensin on määritettävä radanopeus, minkä jälkeen voidaan päällystepaksuuden, kosteuden, pohjaradan neliöpainon ja päällysteen kiintoainepitoisuuden perusteella määrittää kosteus tai kosteuden muutos $\Delta H20$ ennen kuivausta. Kosteuden asetusar-

vo summataan mitatun eli kosteuden oloarvon kanssa, jolloin saadaan oloarvon ja asetusarvon erotus ΔM, josta voidaan laskea tarvittava kuivatustehon muutostarve, ΔH20, joka summataan mahdollisiin prosessin muutoksista aiheutuviin muutoksiin. Näin saadun kuivainten kuivaustehon muutostarpeen perusteella lasketaan tarvittavat kuivatustehot ja uudet kuivainten asetusarvot käyttäen prosessin kokonaismallia ja prosessiolosuhteiden ja prosessin tilan arvoja. Uudet asetusarvot ilmoitetaan kuivaimille.

Keksinnön mukaista menetelmää voidaan soveltaa kaikenlaisiin paperin tai kartongin päällystysmenetelmiin ja laitteisiin, joissa pohjaradan pinnalle levitetään nestettä sisältävää päällysteseosta, joka kuivataan yhdellä tai useammalla kuivaimella. Tavallisesti järjestelmässä on kuitenkin useita kuivaimia ja keksinnön edut ovat sitä suuremmat, mitä monimutkaisemmasta päällystyskoneesta on kyse.

Patenttivaatimukset:

1. Menetelmä paperin tai kartongin päällystyksessä käytettävän ainakin yhden päällystysaseman (1) ja ainakin yhden kuivaimen (2 - 6) käsittävän laitekokonaisuuden kuivatustehon säätämiseksi, jossa menetelmässä,

- levitään radan (8)pinnalle nestettä sisältävää päällysteseosta,

- kuivataan päällysteseoksella päällystettyä rataa (8) haihduttamalla siitä nestettä kunnes radan (8) kosteuspitoisuus on haluttu,

- muodostetaan niille päällystyskoneen osille, joilla kosteutta poistuu radasta (8), ominaishaihdutusmalli, joka kuvaa tällä osalla poistuvan nesteen määrää, ja

- määritetään tarvittava kokonaishaihdutusteho,

t u n n e t t u siitä, että

- ketjutetaan eri osien ominaishaihdutusmallit kokonaishaihdutusmalliksi,

- jaetaan tarvittava kokonaishaihdutusteho kokonaishaihdutusmallin mukaisesti laitekokonaisuuden kuivaimille, ja

- määritetään kuivaimille mallin mukaiset uudet ohjausarvot.

2. Patenttivaatimuksen 1 mukainen menetelmä, t u n n e t -

t u siitä, että laitekokonaisuuden yhden kuivaimen tehoa säädetään kokonaishaihdutusmallin avulla ja muiden kuivainten teho asetetaan kiinteään arvoon.

3. Patenttivaatimuksen 1 mukainen menetelmä, t u n n e t t u siitä, että ainakin kahden laitekokonaisuuden kuivaimen tehoa säädetään kokonaishaihdutusmallin avulla.

4. Patenttivaatimuksen 1 mukainen menetelmä, t u n n e t t u siitä, että mitataan ainakin radan (8) loppukosteus, verrataan mitattua kosteusarvoa asetusarvoon ja lasketaan kokonaishaihdutusmallin avulla kuivaimille uudet haihdutusmäärän asetusarvot.

5. Patenttivaatimuksen 4 mukainen menetelmä, t u n n e t t u siitä, että mitataan radan kosteus ainakin yhdessä pisteessä ennen loppukosteuden mittaamista ainakin yhden välikosteuden määrittämiseksi ja lasketaan mittaustuloksen avulla ainakin mittauskohtaa edeltäville kuivaimille uudet haihdutusmäärän asetusarvot.

6. Patenttivaatimuksen 1 mukainen menetelmä, t u n n e t t u siitä, että määritetään radan alkukosteus ja sille tuotu vesimäärää, lasketaan tarvittava kokonaishaihdutusmäärä ja asetetaan kokonaishaihdutusmallin avulla kuivainten tehot siten, että saavutetaan haluttu loppukosteus.

7. Patenttivaatimusten 5 ja 6 mukainen menetelmä, t u n n e t t u siitä, että asetetaan kuivainten tehot mallilaskennan ja mittaustuloksen perusteella.

8. Patenttivaatimuksen 2 mukainen menetelmä laitekokonaisuuden kuivainten ominaishaihdutusmallien malliparametrien

korjaamiseksi, t u n n e t t u siitä, että

- asetetaan yksi laitekokonaisuuden kuivain toimimaan kokonaishaihdutusmallin ohjauksen mukaan,

- asetetaan laitekokonaisuuden muut kuivaimet toimimaan vakioteholla,

- muutetaan mallisäätöisen kuivaimen ohjaussignaaleja,

- verrataan kokonaishaihdutusmallin antamaa kosteusarvoa mitattuun arvoon, ja

- lasketaan mitatun ja mallin mukaan lasketun estimaatin erotuksen avulla korjatut ominaishaihdutusmalliparametrit mallisäädölle asetetulle kuivaimelle.

9. Patenttivaatimuksen 8 mukainen menetelmä, t u n n e t t u siitä, että mallisäätöisen kuivaimen ohjaussignaaleja muutetaan askelmaisesti tai kytkemällä asetuksiin Pseudo-Random-Binary-signaali (PRBS).

10. Patenttivaatimuksen 1 mukainen menetelmä, t u n n e t t u siitä, että laitekokonaisuuden edellisen kuivaimen ominaishaihdutusmallin antamia lähtöarvoja käytetään seuraavan kuivaimen ominaishaihdutusmallin tuloarvoina.

11. Patenttivaatimuksen 4 mukainen menetelmä, t u n n e t t u siitä, että jaetaan tarvittava haihdutustehon muutos kokonaishaihdutusmallin avulla säädettävien kuivainten kesken ennalta asetettujen painokertoimien suhteessa.

12. Patenttivaatimuksen 1 mukainen menetelmä ainakin kaksi

päällystysasemaa ja vastaavat kuivaimet käsittävän laitekokonaisuuden kuivatustehon säätämiseksi, t u n n e t t u siitä, että ketjutetaan päällystysaseman ja vastaavat kuivaimet käsittävien osajärjestelmien kokonaishaihdutusmallit ainakin lähettämällä edellisen osajärjestelmän mallille seuraavan osajärjestelmän jälkeinen mitattu ratakosteuden arvo.

13. Patenttivaatimuksen 1 mukainen ainakin kaksi päällystysasemaa ja vastaavat kuivaimet käsittävän laitekokonaisuuden kuivatustehon säätämiseksi, t u n n e t t u siitä, että ketjutetaan päällystysaseman ja vastaavat kuivaimet käsittävien osajärjestelmien kokonaishaihdutusmallit keskenään muodostamalla osajärjestelmien kokonaishaihdutusmalleista laitekokonaisuuden kokonaishaihdutusmalli.

PCT/FI00/00166

(57) Tiivistelmä

Menetelmä, jonka avulla päällystettävän radan koneensuuntaista kosteutta voidaan säätää optimoidusti koko päällystys- ja kuivatustapahtuman kosteudenmuutokset huomioon ottaen. Päällystyskoneen kaikkia kuivaimia säädetään integroidusti hallitun ja energiankulutuksen sekä valmistuslaadun kannalta optimaalisen lopputuloksen saavuttamiseksi. Jokaiselle radan kuivumiseen vaikuttavalle prosessin osalle ja laitteelle muodostetaan matemaattinen ominaishaihdutusta kuvaava malli ja yksittäisten mallien avulla muodostetaan malleja ketjuttamalla kokonaisprosessin malli, jonka avulla hallitaan prosessin kuivatustapahtumaa siten, että yksittäisiä laitteita ohjataan prosessin osana.

Fig. 1

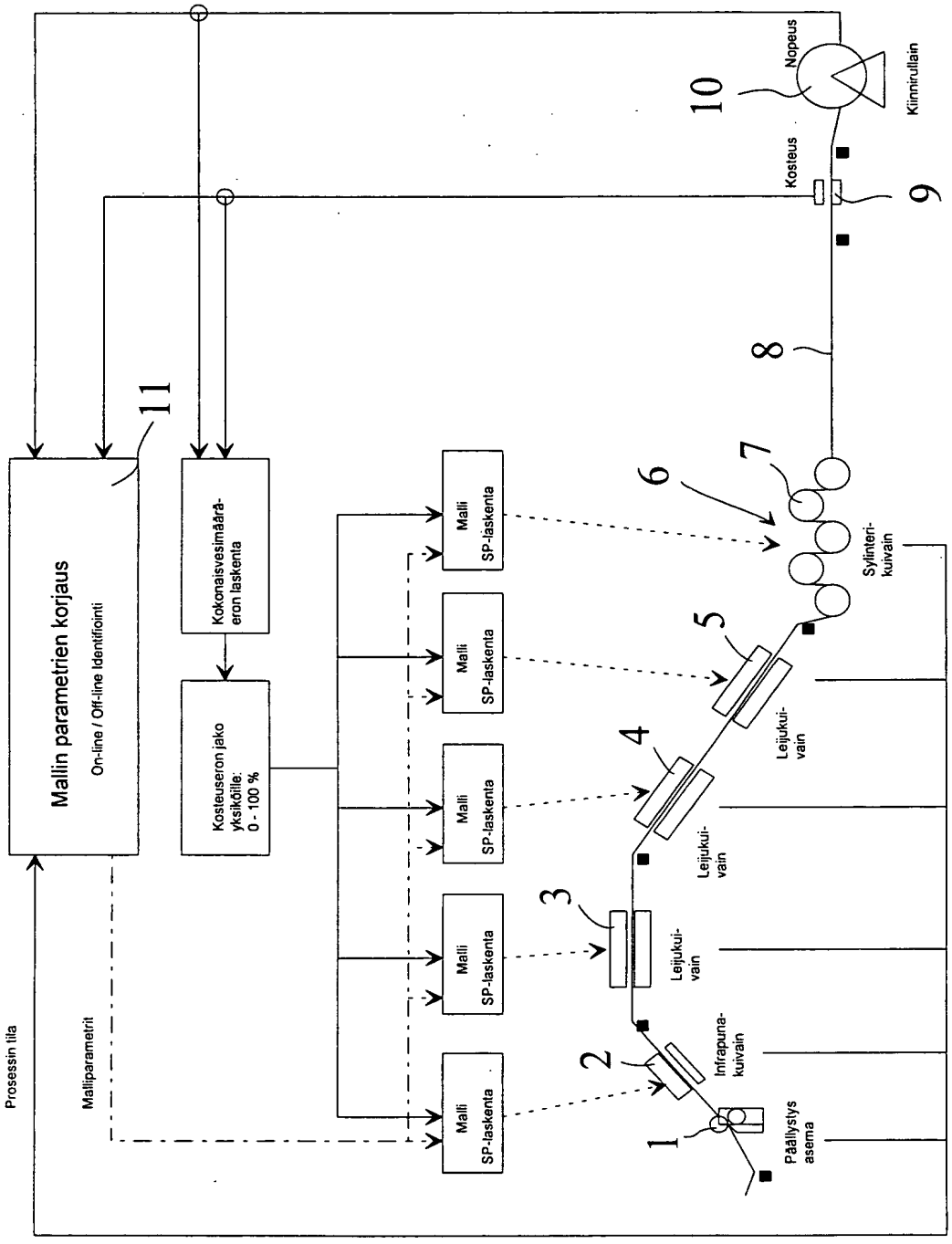
Mallin parametrien korjaus
On-line / Off-line Identifiointi
Kokonaisvesimäärä-eron laskenta
Kosteuseron jako yksiköille: 0 - 100 %
Malli SP-laskenta
Malli SP-laskenta
Malli SP-laskenta
Malli SP-laskenta
Malli SP-laskenta
Prosessin tila
Malliparametrit
Päällystys asema
Infrapuna-kuivain
Leijukui-vain
Leijukui-vain
Leijukui-vain
Sylinteri-kuivain
Kosteus
Nopeus
Kiinnirullain
1
2
3
4
5
6
7
8
9
10
11

Fig. 1

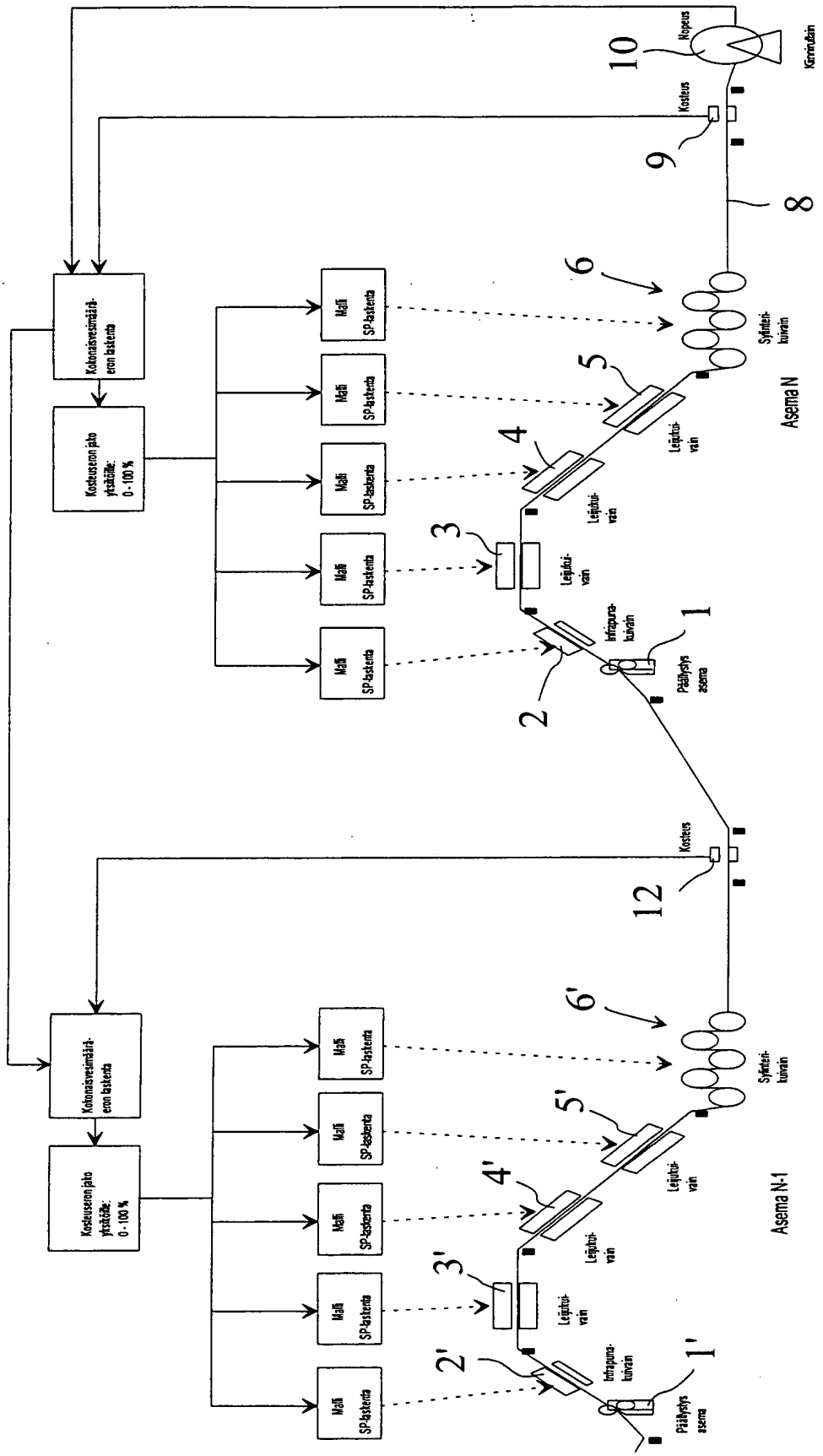
Kokonaisvesimäärä-eron laskenta
Kosteuseron jako yksiköille: 0 - 100 %
Malli SP-laskenta
Malli SP-laskenta
Malli SP-laskenta
Malli SP-laskenta
Malli SP-laskenta
Nopeus
Kosteus
Kiinnidain
10
9
8
6
5
4
3
2
1
Leijutuivain
Leijutuivain
Leijutuivain
Infrapuna-kuivain
Päällystys asema
Syöttei-kuivain
Asema N
Kokonaisvesimäärä-eron laskenta
Kosteuseron jako yksiköille: 0 - 100 %
Malli SP-laskenta
Malli SP-laskenta
Malli SP-laskenta
Malli SP-laskenta
Malli SP-laskenta
Kosteus
12
6'
5'
4'
3'
2'
1'
Leijutuivain
Leijutuivain
Leijutuivain
Infrapuna-kuivain
Päällystys asema
Syöttei-kuivain
Asema N-1

Fig. 2

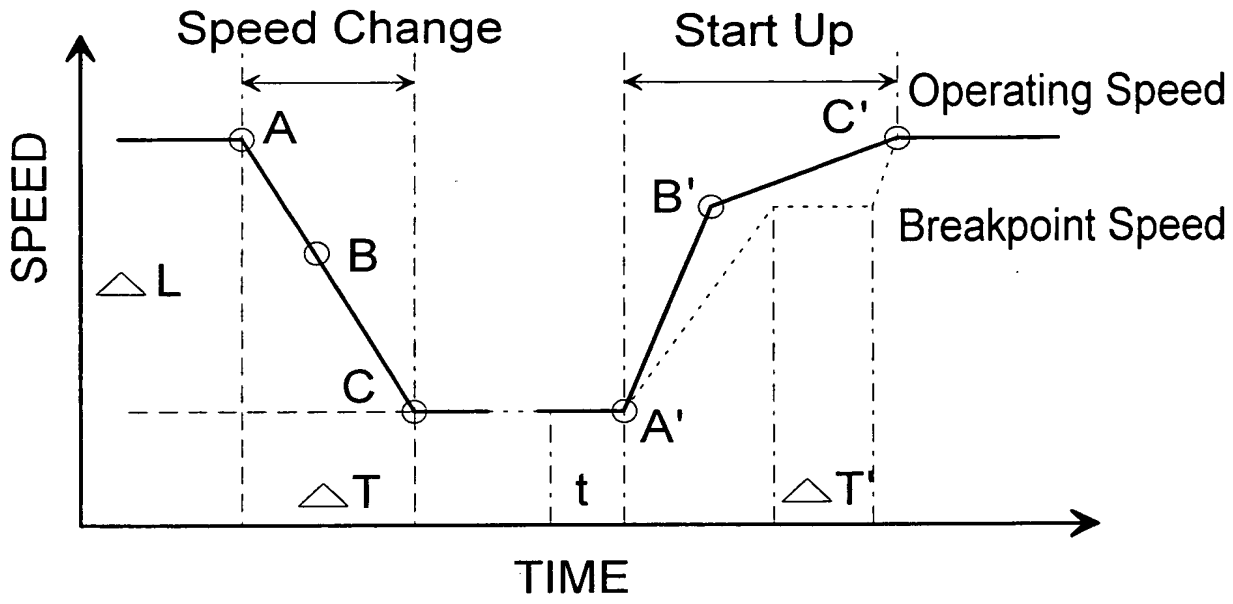
Speed Change
Start Up
Operating Speed
Breakpoint Speed
SPEED
TIME
A
B
C
A'
B'
C'
△L
△T
t
△T'

Fig. 3

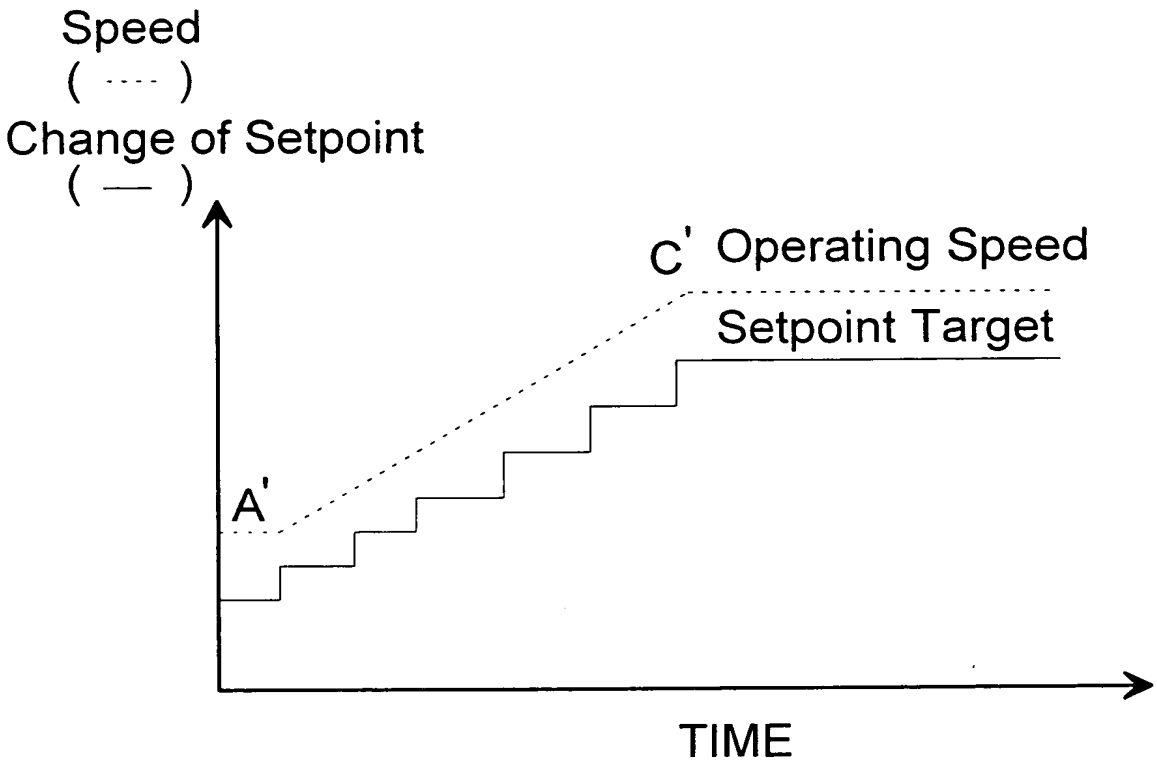
Speed
(····)
Change of Setpoint
(—)
C' Operating Speed
Setpoint Target
A'
TIME

Fig. 4

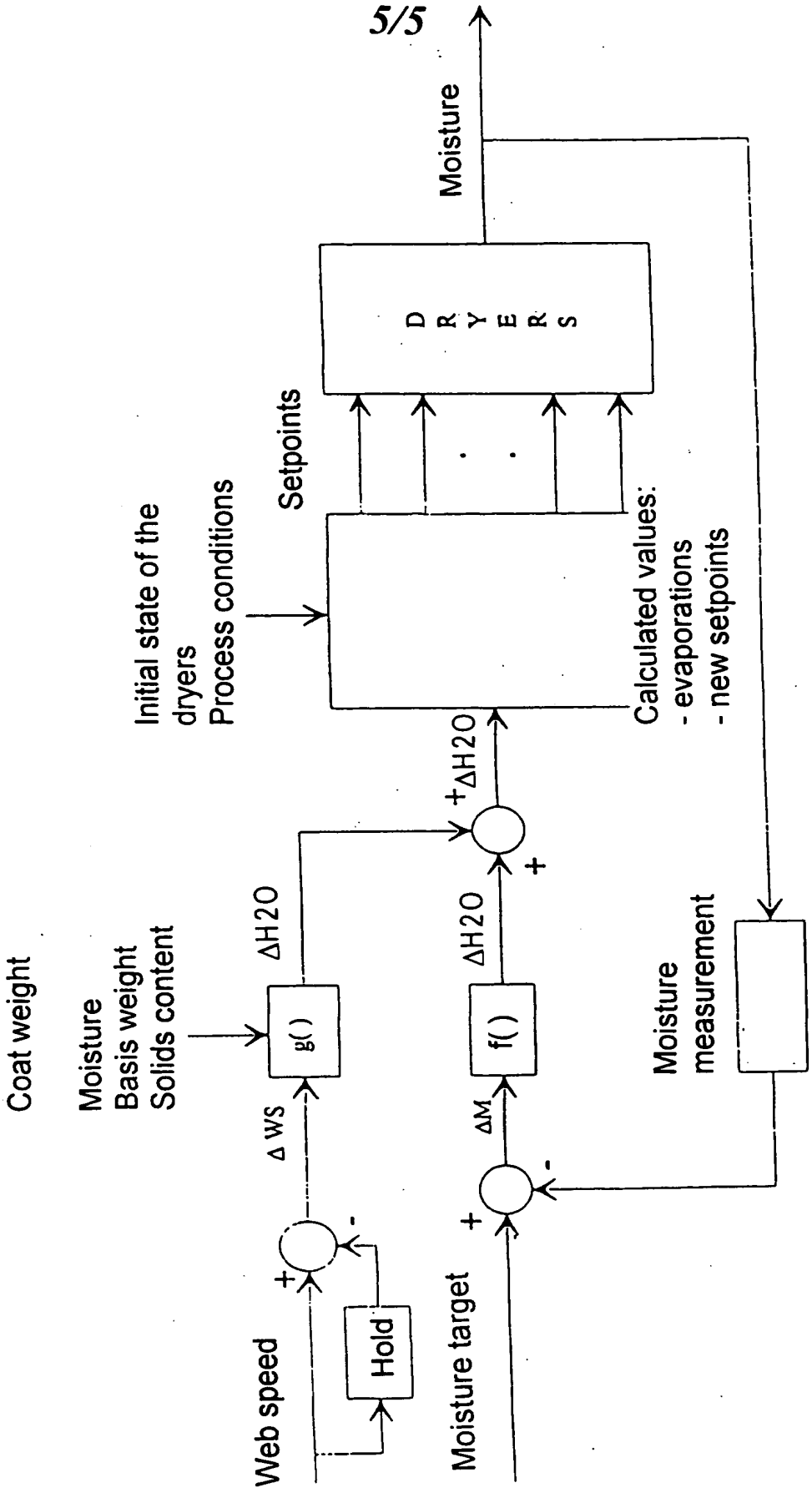
Moisture
D R Y E R S
Setpoints
Initial state of the dryers Process conditions
Calculated values:
- evaporations
- new setpoints
+ΔH2O
ΔH2O
ΔH2O
Coat weight
Moisture
Basis weight
Solids content
g( )
f( )
Moisture measurement
Δ WS
ΔM
Web speed
Hold
Moisture target
+
-
+
-
+
+

FIG. 5

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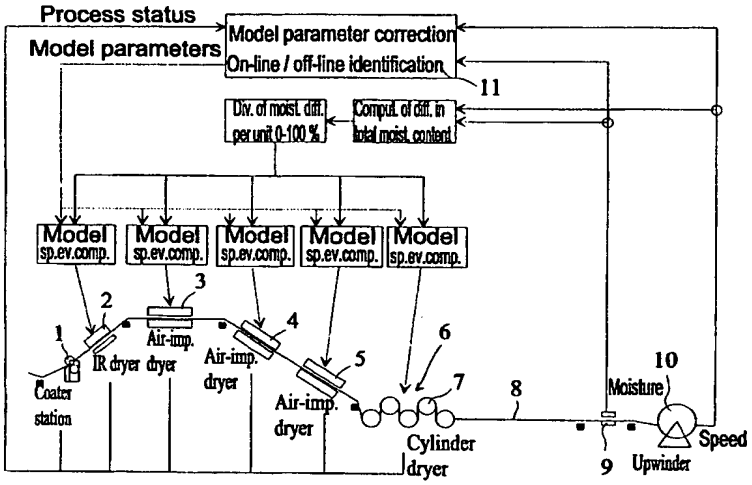
(54) Title: METHOD FOR CONTROLLING THE MOISTURE OF A WEB IN MACHINE DIRECTION ON A COATING MACHINE



(57) Abstract

The invention relates to a method by means of which the machine–direction moisture of a web being coated can be controlled in an optimal manner that takes into account moisture content changes along the entire path of the coating and drying process. Advantageously, all the dryers of the coater section are controlled in an integrated manner in order to obtain a controlledly processed product which is optimized in regard to energy consumption and product quality. Each process section and unit contributing to the drying of the web is identified by means of a mathematical submodel describing the specific evaporation rate in the respective process section/unit and, by chaining these submodels, a composite model is compiled for the entire process, whereby the composite model makes it possible to manage the drying operation in the process so that the individual units are controlled as a portion of the overall process.

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Method for controlling the moisture of a web in machine direction on a coating machine.

The present invention relates to a method according to the preamble of claim 1 based on a novel control and steering strategy for use in the drying process of a paper web or similar coated web material such as board in coater sections in which the web to be coated is passed via a coater station including at least one applicator apparatus and dryers.

In the coating of a web of paper or board, the surface of the web is first coated with a furnish containing coating pigments slurried in water. After the application and smoothing of the coating mix, the coating applied to the web surface as well as the underlying base web must be dried to a sufficiently low moisture for final use or further processing. Hence, a major portion of the energy consumed in the production of coated paper grades is lost in drying the web during the different steps of postprocessing, which means that energy management in drying is an extremely vital factor contributing to the profitability of production. Correct drying technique also affects the quality of the produced paper grade. Another parameter highly pertinent to the quality of produced paper is the control of the machine-direction moisture profile, that is, the moisture of the base paper, which must be kept at a constant level during the run. The web moisture content affects particularly the paper web behavior in calendering and printing. As modern production lines are equipped with on-line calendering,

wherein the coated web is passed directly to a calender, the moisture profile of the running web has an insufficient time to reach a uniform equilibrium state prior to calendering, a situation which is in contrast to that attainable in the traditional off-line calendering, wherein the coated web was stored in a machine reel prior to subsequent calendering. Correspondingly, the transport chain of paper from the mill to printing houses and other users has been speeded up, whereby the moisture even in uncalendered paper does not necessarily have enough time to stabilize and reach a sufficiently low level prior to printing. In coating, the web moisture content affects the penetration of water into the base web during the application of the coating mix and, resultingly, the change of coating solids content after coating. As variations in the solids content of the coating are reflected in plural parameters in the application process, it is important to keep the web moisture during application and drying accurately within proper limit values in order to attain a uniform and desired final quality of the product.

Conventionally, a coated web is dried immediately after the application of coating using noncontacting dryers, which step may be followed when necessary by cylinder dryers and other dryers of the contacting type. The moisture content of the running web is measured at multiple points along the web travel in the coater apparatus and, on the basis of the measurement data, the drying effect of each dryer is individually adjusted so as to attain a proper web moisture over the cross-machine width at the respective measurement point as well as an average

moisture content that stays between given limits during a run, the latter requirement meaning that the machine-direction moisture profile is controlled to a given set value. The overall drying capacity is adjusted to a suitable basic level based on test runs and data accumulated from a long-term experience in the art, and the individual dryer effects are then fine-tuned during the run on the basis of measurement data either automatically or manually. Conventionally, one of the dryers or one dryer group is selected to perform as the controller of the final moisture level, whereby the heating power input to the selected dryer group(s) is adjusted by means of a feedback signal obtained from the measurement system. In this arrangement, the other dryers are driven under manual control. Such a control scheme responds very tardy and compensation for the slow response of dryer control is difficult to implement in situations requiring a fast change of dryer effect levels. Furthermore, the web temperature prior to the coater apparatus must be kept sufficiently low to avoid floccing of the coating mix being applied. Hence, proper control of the drying effect is important particularly in the final stage of the dryer section prior to the subsequent coating step. The web temperature also affects the final quality of the coated web.

Particularly in situations of changing running conditions or when starting up the machine, known in the art as the run-up, the elevation of the dryer drying effect levels to correct values and adjustment of the same to proper run-time levels requires excellent skills from the personnel operating the machine. However, carrying out

the procedure of setting the dryer evaporation effect levels in the coater section to correct values under run-up or changing process conditions takes time, during which the produced paper or board falls short of the specified quality requirements thus necessitating dumping of the web into the pulper. Hence, it is advantageous to minimize the durations of run-up and process value change times in order to achieve improved production efficiency at the machine. The above control scheme is also extremely clumsy in the optimization of drying energy consumption inasmuch it relies on the control of each dryer unit separately, whereby the mutual evaporation effect ratios between the dryer units are difficult to alter in an uncomplicated manner. Furthermore, a failure in one or a greater number of the dryer units is difficult to compensate for, because the process is designed for operation with all the dryer units being functional.

It is an object of the present invention to provide a method suited for controlling the machine direction moisture profile of a web to be coated in a manner optimized to respond to any moisture changes throughout the entire coating/drying process. In practice this approach means the application of a comprehensive control scheme covering all the dryer units of a coater section in an integrated manner in regard to energy consumption and product quality in order to attain an optimal end result.

The goal of the invention is achieved by way of forming a mathematical submodel of specific moisture evaporation rate for each process section and device contributing to

the web drying process and then chaining the thus obtained individual submodels so as to form a composite model of the overall process, the model being suited for managing the drying phenomena during the entire process so that each individual unit of the equipment layout is controlled as a part of the overall process.

More specifically, the method according to the invention is characterized by what is stated in the characterizing part of claim 1.

The invention offers significant benefits.

By virtue of the model according to the invention, it is possible to directly compute the moisture content of the web at the outgoing side or each dryer, provided that the specific evaporation rate at the dryer and the web moisture at the ingoing side are known. After the chaining of the individual submodels, the web moisture content can be computed at different points along the coater section, the most important parameter value obviously being the final moisture content of the web. With the help of the model, the dryer effects may be adjusted according to the individual properties so that the characteristics of different types of dryers are optimally taken into account. Since infrared dryers feature a quick response, they may be used, e.g., during run-up for controlling the overall effect of the dryer group, thus allowing the evaporation effect levels of other dryers to be elevated in a more relaxed manner to their steady-state values during the normal run by way of compensating for the delay of dryer warm-up with the help

of delay terms adapted into the model. The use of delay terms makes it possible to manage actual process response delays, too.

Since the invention provides a control scheme for the overall process, it allows the evaporation effects of the dryer units to be divided therebetween in a desired manner and, particularly in the case of failure in one dryer, the drying effect lost thereby may be compensated for by the other dryer units thus permitting operation of the coater section uninterrupted by a servicing shutdown. Equally, as the initial moisture content of the web as well as the amount of moisture added thereto by the applied coating are known, the model gives tools for computing an estimate for the web moisture at different points along the process and, particularly, prior to upwinding. In fact, the model allows the web final moisture content to be computed so accurately that production may be continued controlled by the model even when the moisture measurement devices are down.

The overall performance offered by the invention gives a faster and more accurate control result than that available by way of manual control combined with feedback loops controlling the individual drying units.

In the following, the invention will be examined in greater detail by making reference to the appended drawings in which

FIG. 1 shows a coater section or a portion thereof comprising one coater station and dryers;

FIG. 2 shows a coater section or a portion thereof comprising two coater stations, each equipped with separate dryers;

FIG. 3 shows a schematic plot of changing web speed in the coater section;

FIG. 4 shows a schematic plot of the control of the dryer effect at a change in the web speed; and

FIG. 5 shows block diagram of the present control method.

Referring to FIG. 1, the diagram shown therein schematically illustrates a layout comprising one coater station 1 with dryers 2 - 6 connected thereto, whereby the functions related to the drying effect control of the dryers 2 - 6 are illustrated as a block diagram. In the downstream travel direction of a web 8, the first unit is a coater station 1 serving to apply coating or other web treatment substance such as surface size to at least one side of the web. As the type of coater station used is irrelevant to the implementation of the invention, the coater may be any suitable applicator apparatus such as a short-dwell coater, film-transfer coater, blade coater or spray coater. The coater station may be used for applying the coating to one side of the web 8 only as is customary, or to both sides, as required. Obviously, the construction of dryers 2 - 6 is dependent on whether two-sided or one-sided coating is performed in a single coater station, but nevertheless the function of any one of the dryers may be modeled in the same fashion in

accordance with the invention.

Next downstream to the coater station are located first an infrared radiant dryer 2, then three air-impingement dryers 3 - 5 and finally a dryer cylinder group 6 comprising a plurality of dryer cylinders 7. On the dryer cylinder group 6, the web 8 is dried to a final moisture content and next the web 8 is passed via a moisture content gage 9 to an upwinder 10.

The process is controlled by means of a computer. The actual implementation of the computer may comprise a module running under the software of the coater section control computer, or a separately allocated computer or microprocessor serving the moisture control task alone or a physically distributed software and database package. The control system contains an evaporation rate submodel for each one of the dryers and a composite evaporation rate model compiled from these submodels. Additionally, the data base 11 of the control system serves to store the process status data, that is, the real-time status of both the coater section and the model obtained by way of measurement or directly from the computational data submitted by control system of the coater section. The status data includes such parameter values as the coater section status comprising the applied coat weight, solids content thereof and other similar factors, dryer evaporation effect levels, the final moisture content after the dryer units and the web speed as measured at the upwinder 10.

In FIG. 2 is shown a system comprising two coater

stations, each equipped with separate dryers. While the exemplifying embodiment is described below for the two last coater stations of a system, a complete layout may include a plurality of such subsystems formed by a coater station with dryers. Then, each subsystem may be described by means of an individual evaporation rate submodel, or more advantageously, a single model is compiled for the entire coater section, thus achieving a simpler control scheme for managing the overall process. In certain cases, particularly the web moisture prior to its entry into a successive coating step may exceed the final moisture content of the web, which means that the average moisture content of the web when passing through the coater section is higher than when the web reaches the upwinder. This kind of situation requires more drying effect after the last coater station than on the preceding stations, which is easy to arrange by virtue of the method according to the invention so that the computed or measured web moisture content value from the output of a next successive subsystem is fed back to the evaporation effect computation of the preceding subsystem. Conventionally, the moisture of web passed from the papermaking machine to the coater is in the range of about 1.5 - 4 %, while the moisture of a treated web in the order of 4 - 6 %. The moisture content values of the web may vary widely during the different phases of web treatment, and also the final and initial moisture contents of the web may vary according to the grade being manufactured. If desired, the initial moisture content of the web may be computed on the basis of the amount of evaporation during a run, this value being obtained from the model, and the final moisture content of the web, this

value being measured prior to the upwinder.

Accordingly, the method according to the invention aims to provide an accurate overall control of the machine direction moisture profile of the web along its entire downstream travel through the coater section in all production situations and, particularly, during the dynamic transition phase toward the steady-state production run condition, that is, during machine run-up and when changes occur in the machine speed or the coating process parameters. The present method is capable of controlling a plurality of coater section dryers simultaneously so that the target value of web moisture is attained optimally. In the novel approach according to the invention, each drying unit is formulated with the help of a mathematical submodel describing the specific evaporation behavior of the unit, whereupon the submodel is utilized in the comprehensive control strategy for computing the unit-specific set values. The thus formulated specific evaporation rate models are used in a chained manner for modeling the overall process, complemented with certain measurement results obtained from the process. The parameters of the mathematical modeling equations may be updated on either per unit or per operating point basis using either off-line or on-line techniques. The thus obtained computational model can be brought to match exactly with the operation of the coater section for different kinds of manufactured product grades and varying process conditions.

The method can be applied to both so-called off-machine and on-machine coater sections, and it is capable of

performing dryer control functions under a normal steady-state production run situation as well as during dynamic transition phases toward a normal production run state. In the context of the present invention, a normal steady-state production run situation is understood to refer to a condition in which no changes occur in the machine speed or, if changes do occur, they are of a type that will not be reflect in the product quality. Such change and transition situation(s) is/are represented by changes in machine speed and start-up of section operation. The measurements values of the process quality monitoring system and other values such as the web moisture, basis weight, coat weight, coat solids content and web temperature sensor signals obtained from the coater section control system serve as the input signals of the method. The measurement sensors of the process quality monitoring system may be located either after the last dryer unit in each coater station and preceding the upwinder, whereby the measurement system represents a comprehensive implementation or a portion of the so-called intermediate points of moisture measurement can be omitted, whereby the method may use the web moisture estimates which are computed from the evaporation model and bear an accurate relationship with the actual situation along the web travel, particularly when the parameters of the modeling equation are updated in real time.

Based on the mathematical models, the present method computes the specific evaporation rate, e.g., as $kgH_2O/m^2/h$ for each dryer or process unit contributing to the drying process. The computations take into account the coater stations, infrared radiant dryers, air-impingement

dryers, cylinder dryers and other dryers associated with the coater section, as well as the open draws between the dryer units. Open draws form an important part of the modeling task and must be included in the composite model, because moisture evaporation also takes place on these portions of the web travel from the hot web exiting the dryers.

On a coater station, the coating applied to the surface of the web carries along a certain amount of excess water that must be removed on the dryers. When the initial moisture content of the web, as well as the amount of applied coating and the moisture content of the coating are known, it is possible on the basis of the web speed to compute the required overall evaporation effect and to divide it between the different dryers. The goal is to control the so-called intermediate moisture of the web after each coater station, as well the final moisture of the finished product to desired target values by means of steering the coater section dryers as an integrated system. The specific evaporation computation utilizes measurement data gathered on web moisture, temperature, speed and on the ambient air humidity. With the help of the specific evaporation models, it is possible to compute an estimate for the moisture of the web leaving any dryer. Similarly, it is possible to compute the change in web temperature within each process unit and the exit temperature of the web at the outgoing side of each unit. A chained composite model for the entire system is obtained by combining the mathematical submodel equations that describe the behavior of the dryers and the open draws. Herein, the values of the web moisture and temper-

ature computed for the outgoing side of a preceding dryer are used as the input values for the next dryer, that is, representing the moisture and temperature values of the entering web.

According to the method, the web intermediate moisture after each coater station and the final moisture content of the finished product at the upwinder are controlled by means of specific evaporation submodels developed for the dryers of the coater section. With the help of these submodels it is possible to compute such set values of adjustment and control variables for each modeled unit that bring about the desired values of web intermediate and final moisture contents. The same approach also is used to manage a machine speed change situation. The control actions are carried out with the help of both closed-loop feedback circuits and feedforward circuits. Moisture measurement signals obtained from the process quality monitoring system are taken to the feedback circuit that adjusts the set values of one or more dryer units in the coater section. The feedforward circuit, which is employed to manage the dynamic transition states of machine speed change, uses set value estimates which are computed from the mathematical submodels of the specific evaporation rates for the final condition of the machine speed change state. This description, however, omits the details of the actual modeling techniques used inasmuch those skilled in the art have no difficulty in finding the needed mathematical tools in the literature.

The first step in the method according to the invention is to compute the specific evaporation rates for the dif-

ferent units of the production line. The specific evaporation rates as $kgH_2O/m^2/h$ are computed for the separate dryers of the coater section using the computational facilities of the automation system of the production line or of a separate computing unit intimately communicating therewith. The mathematical submodels of the coater section dryers are developed separately for the coater stations, infrared radiant dryers, air-impingement dryers and cylinder dryers and other dryers possibly cooperating with the coater section, and for the open draws. The mathematical submodels take into account the contribution of the characteristic control parameters of each unit and the effect of process variables on the overall specific evaporation rate. Such contributing variables include the web speed, the web initial moisture and temperature, the web basis weight, the coat weight, the solids content and composition of applied coating, air humidity, the lineal effect (kW/m) of the infrared radiant dryer, the temperature and flow rate of impinging air blown in the air-impingement dryer, and the steam pressure and flow rate in cylinder dryers. As an outcome of the computation, the submodels give the specific evaporation rate for each dryer, the web moisture at the outgoing side of the dryer and the web temperature at a given point of interest when properly selected control variables are used in the equations.

With the help of data obtained from the process quality monitoring system, the characteristic parameters of the evaporation rate submodels may be corrected, e.g., as per paper grade and system operating status. In this fashion, the composite model can be tuned to accurately match the

actual operating status and the behavior of the coater section to be controlled. To this end, the estimate obtained from the model for the web moisture at a given point of the web travel, e.g., prior to upwinding, is compared with the actual moisture data obtained from the web measurement sensors. On the basis of this comparison, an error term is computed for the model that is then used in the correction computation for the model parameters. The correction computation may be carried out as either an off-line task within the automation system of the production line or other computing system connected thereto or alternatively, directly as an on-line task in the automation system, using appropriate computing routines such as the least squares method, for instance, or equivalent recursive algorithms. For this purpose, the dryers are controlled according to a specific strategy so that all the dryers are set to a constant evaporation effect state, with the exception of the one for which the equation parameters of the submodel are to be analyzed. During the parameter value update operation, the control signals of the dryer being analyzed are appropriately varied in accordance with the parameter identification technique used, e.g., by way of imposing stepwise changes in the set value or superimposing a PRBS (pseudo-random binary signal) on the set value output signals in order to cause a sufficient amount of changes in the system being analyzed so that the computational algorithm of the parameter identification technique will converge. The thus obtained parameter values of the modeling equations as per paper grade and process operating point can be stored in a separate database or in the grade-specific production control files of the process automation

system.

According to the invention, moisture control along the downstream travel of the web takes place as follows. In the method described herein, a model-based web moisture controller computes from the actual measurement signal of the web moisture and the target value of the web moisture a control signal, whereby the computational process utilizes a composite model compiled from the mathematical submodels of the individual dryers. The computation takes into account the specific evaporation rates of the dryers and the prevailing manufacturing process conditions. With the help of the submodels, such set values of adjustment and control variables are computed for each dryer separately that are required to attain the desired intermediate and final values of web moisture. During dynamic changes of machine speed, the control algorithm computes the need for effect change in the dryers according to the change in web speed.

In a normal steady-state production run situation involving no change in web speed, a feedback-type control scheme is used, whereby the model input signals formed by the web moisture set value and the actual web moisture measurement information are processed into a feedback signal of moisture error, on the basis of which signal the control algorithm then performs required changes to an extend defined by the system operator in the drying effects of dryers selected to be controlled by the control computer. While all the dryers may be set to be controlled by a computer or, respectively, set for manual control, in the spirit of the invention the drying effect

of at least one dryer must be steerable by means of a model running on a computer. Herein, as shown in FIG. 2, either the intermediate point moisture sensor 12 or the process quality monitoring system sensor 9 preceding the upwinder 10 give the actual web moisture content value that is compared by the control program with the set value. On the basis of the difference between the set value and actually measured web moisture, the system computes the respective change of the overall moisture (ΔH_2O) that should be accomplished by means of the dryers selected to be steered by the control computer. If the moisture difference signal has a positive sign, the specific evaporation rate must be increased. Respectively, a negative sign indicates a need for reduced specific evaporation rate. The overall value of required moisture change (ΔH_2O) is divided between the dryers ($i = 1...N$) selected to be steered under computer control using such proportional percentage weight factors (0 - 100 %) that the sum of the weighting factors always is 100 %. Obviously, other weighting strategies are also possible in the division of moisture change, that is, to implement the required change in the distribution of the drying effect between the dryers. For instance, the weighting factors may be selected to be proportional to the available evaporation rate capacities on the modeled dryers or to the desired moisture values at the intermediate points. In this kind of proportional division, each of the selected dryers is allocated to handle so much of the overall moisture difference control task as is indicated by its weighting factor. The specific evaporation rate models are then used for computing the required changes in the set values of control signals

given to each one of the selected dryers. After computation, the new set values are transmitted to the unit controllers that implement the changes in the set values.

In FIG. 3 is shown a situation involving a change in the machine speed. In this case, the control scheme relies on a feedforward circuit. To perform a change in the machine speed from point A of the diagram to point C, the procedure goes as follows. The new set values required at point C for the dryers of the coater section are computed at point A using the submodel equations so that the correction to be made in the set values due to the machine speed change are taken into account. The new set values can be transmitted to the unit controllers either immediately at the start of the machine speed change (point A) or incrementally over the entire duration of the machine speed change phase as shown in the diagram of FIG. 4. The choice of either control strategy is dictated by the amount of machine speed change (ΔL), duration of the change (ΔT) and the dynamic behavior of the selected dryer. During machine run-up, the control strategy can be, e.g., as shown in the right-hand plot of FIG. 3. The new set values required for the unit controllers at either point B' or point C' are computed at point A' with the help of the modeling equations. If the acceleration of the machine takes place via an intermediate point B', the corresponding set values for the target speed at point C' can be transmitted at either points A', B' or in an incrementally stepwise manner (see FIG. 4). For controlling such fast-response dryers as infrared radiant dryers, a desired number of incremental point values may be computed on the basis of the set value start and end

points, whereby the incremental values are activated when the machine attains a speed corresponding a given set value. On the other hand, if the slow dynamic response at, e.g., air-impingement dryers and cylinder dryers (characterized by a delay time t) is taken into account, the set values corresponding to point C' for the selected units may be transmitted already at point (A'- t) or the delayed response may compensated for in the incremental control. The intermediate point B' is most conventionally used, e.g., for shutting down the coater stations. Herein, depending on the time span ($\Delta T'$), it is possible to compute also for point B' the set values of the unit controllers that are then used as the input values in the computation of variable set values for transition toward state C'. The method can also handle situations in which full-width moisture measurement information obtained from the product quality monitoring system or partial-width moisture profile measurements are utilized during machine speed changes or system run-up. In a partial-width moisture profile measurement, the moisture sensor of the product quality monitoring system may be of a so-called fixed type (nontraversing) or the sensor may be arranged to perform a traversing movement, that is, in the cross-machine direction, only for a partial width of the web covering the web by 0.5 - 1.0 m, for instance. In this case the arrival of a new, reliable moisture measurement value always triggers a corrective action performed with the help of the modeling equations or other correction computation on the estimates of set values transmitted to the dryers.

In FIG. 5 is shown the above-described control strategy

in a slightly different diagram. The control scheme illustrated in this block diagram is equivalent to that shown in FIGS. 1 and 2. The left-hand part of the diagram depicts the determination of the moisture difference value. To this end, the first step is to measure the web speed, whereupon it is possible to employ the data on coat thickness, moisture, base web basis weigh and coat solids content in the determination of the web moisture or change of moisture ΔH_2O at the ingoing side of a dryer. When the moisture set value is summed with the measured value, or the actual value, of web moisture, the result is the difference ΔM between the set value and the actual value, wherefrom is possible to compute the needed drying effect change ΔH_2O that must be summed with other possible changes caused by process deviations. On the basis of the thus obtained need for drying effect change, the needed drying effects and new dryer set values are computed with the help of the composite model of the process and the actual values of process conditions and process status. After computation, the new set values are transmitted to the dryers.

The method according to the invention can be applied to all kinds of paper/board coating techniques and equipment in which the surface of a base web is coated with a liquid-based that is dried on at least one dryer. Generally, however, the layout comprises plural dryers and, in fact, the benefits of the invention will be the greater the more complicated the coater section is.

What is claimed is:

1. Method for controlling the drying effect of an equipment layout used in making a coated web of paper or board, the layout comprising at least one coater station (1) and at least one dryer (2-6), the method comprising the steps of

- applying a liquid-containing coating furnish to the surface of the web (8),

- drying the web (8) coated with said coating furnish through evaporating said liquid off from the web until the moisture content of the web (8) reaches a desired value,

- compiling, for each one of those portions of the coater section in which moisture is evaporated from the web (8), a specific evaporation rate submodel suited to compute the amount of liquid removed within the confines of said portion, and

- determining the needed overall evaporation effect,

c h a r a c t e r i z e d in that

- said specific evaporation rate submodels are chained into a composite evaporation rate model,

- the needed overall evaporation effect is divided with the help of the composite model between the dryers of the equipment layout, and

- the model is used in the determination of new control variable set values to be issued to said dryers.

2. Method according to claim 1, c h a r a c t e r - i z e d in that the evaporation effect of one dryer of the equipment layout is controlled with the help of the composite evaporation rate model and the effect of the other dryers is set to a fixed value.

3. Method according to claim 1, c h a r a c t e r - i z e d in that the evaporation effect of at least two dryers of the equipment layout are controlled with the help of the composite evaporation rate model.

4. Method according to claim 1, c h a r a c t e r - i z e d in that at least the final moisture content of the web (8) is measured, the measured moisture value is compared with the moisture set value and, using the composite model, new set values of evaporation rate are computed to be issued to said dryers.

5. Method according to claim 4, c h a r a c t e r - i z e d in that the web moisture is measured in at least one point along the web travel preceding said final moisture content measurement in order to determine at least one intermediate moisture content value and, utilizing said measured moisture value, new set values of evaporation rate are computed to be issued to at least those dryers that are located upstream prior to said intermediate moisture measurement point.

6. Method according to claim 1, c h a r a c t e r - i z e d in that first the initial moisture content of the web and the amount of water applied thereto are determined, the needed overall evaporation is computed and, using said composite model, the evaporation rates of said dryers are controlled to set values that render the end product a desired moisture content.

7. Method according to claims 5 and 6, c h a r a c - t e r i z e d in that effects of said dryers are controlled on the basis of model computation and measurement results.

8. Method according to claim 2 for correcting the model parameters of the specific evaporation rate submodels of dryers in an equipment layout,

c h a r a c t e r i z e d in that

- one dryer of the equipment layout is set to operate under the control of the composite evaporation rate model,

- the other dryers of the equipment layout are set to operate at a fixed evaporating effect,

- the control signals of the model-controlled dryer are varied,

- the web moisture value obtained from the composite evaporation rate model is compared with a measured

web moisture value, and

- corrected values of specific evaporation rate model parameters are computed on the basis of the difference between the measured value and the estimate value computed with the help of the model for the dryer selected to be run in the model-controlled mode.

9. Method according to claim 8, c h a r a c t e r - i z e d in that the control signals of said model-controlled dryer are changed in a stepwise manner or by superimposing a pseudo-random binary signal (PRBS) on the set values.

10. Method according to claim 1, c h a r a c t e r - i z e d in that the output values obtained from the specific evaporation rate submodel of a preceding dryer of an equipment layout are used as the input values in the specific evaporation rate submodel of the next successive dryer.

11. Method according to claim 4, c h a r a c t e r - i z e d in that the needed change in the evaporation effect is divided between the dryers selected to be controlled with the help of the composite model proportionally in ratios determined by preset weighting factors.

12. Method according to claim 1 for controlling the evaporation effect in an equipment layout comprising at least one coater station with its associated dryers,

c h a r a c t e r i z e d in that the composite evaporation rate models describing the behavior each subsystem comprising a coater station and the associated dryers are chained by submitting to the preceding composite model the web moisture value measured downstream after the next successive subsystem.

13. Method according to claim 1 for controlling the evaporation effect in an equipment layout comprising at least one coater station with its associated dryers, c h a r a c t e r i z e d in that the composite evaporation rate models of each subsystems comprised of a coater station with its associated dryers are chained mutually in order to compile a composite evaporation rate model for the entire equipment layout from said composite evaporation rate models of said subsystems.

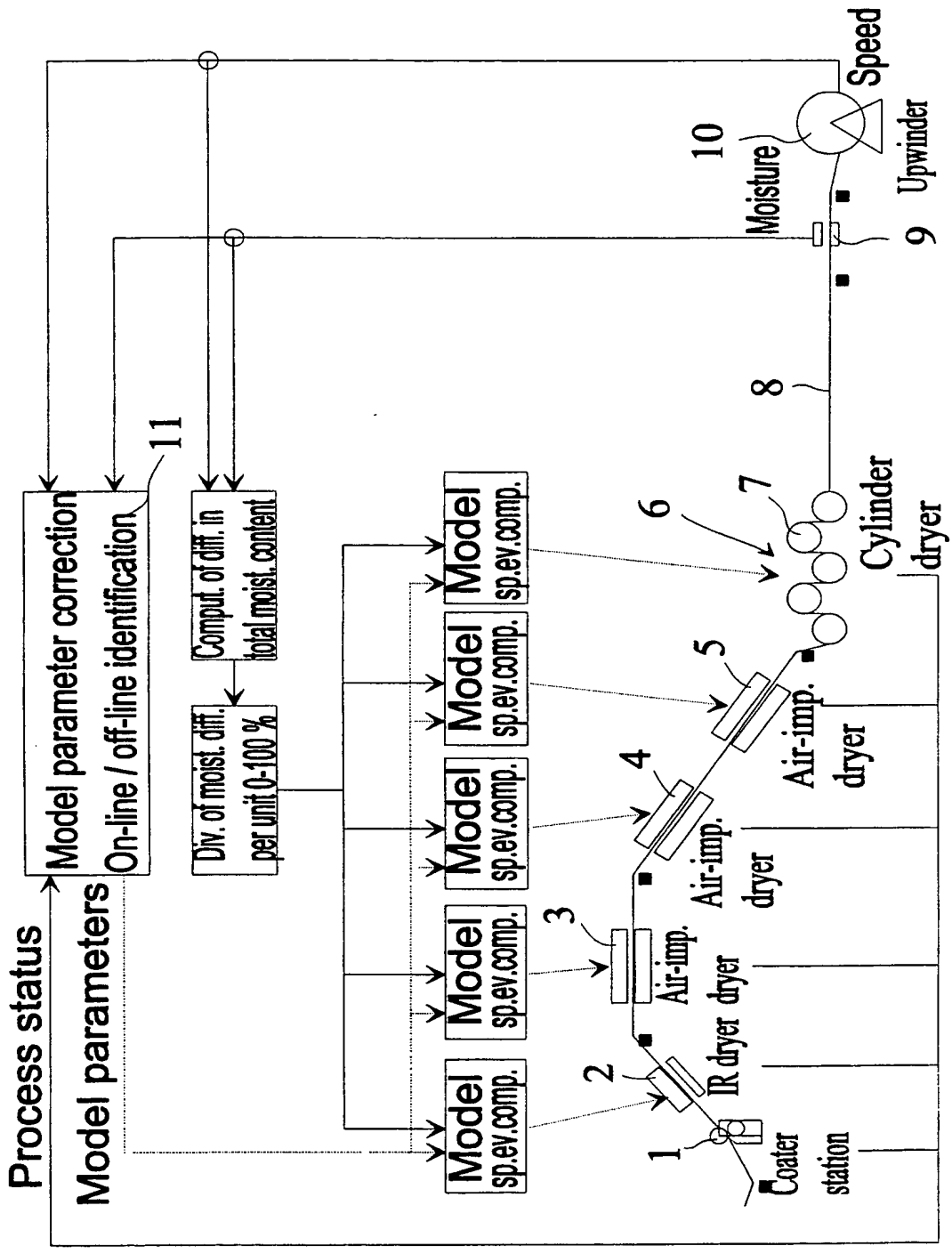
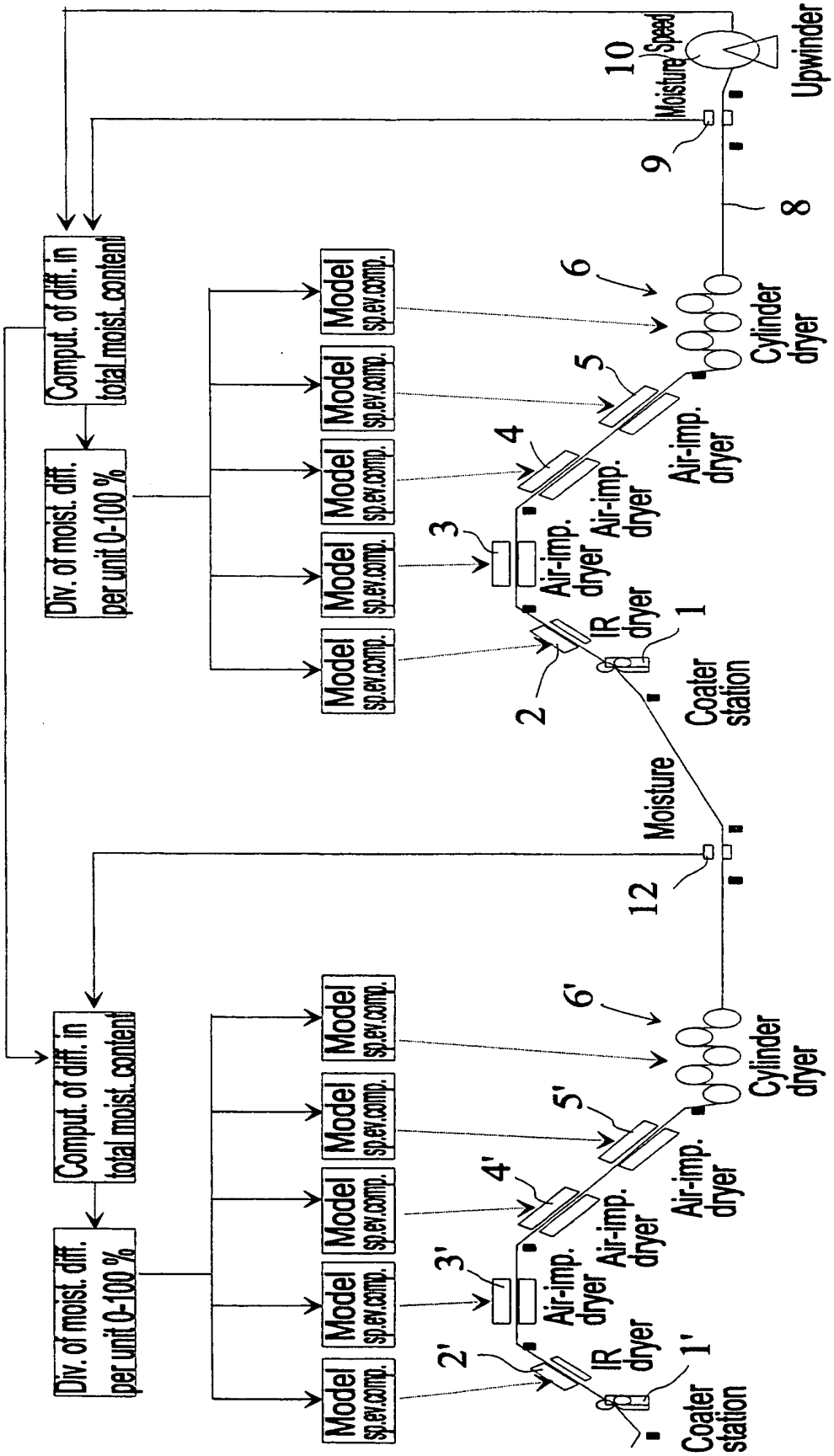

Process status
Model parameters
Model parameter correction
On-line / off-line identification
11
Compt. of diff. in total moist. content
Div. of moist. diff. per unit 0-100 %
Model sp.ev.comp.
Model sp.ev.comp.
Model sp.ev.comp.
Model sp.ev.comp.
Model sp.ev.comp.
1
Coater station
2
IR dryer
3
Air-imp. dryer
4
Air-imp. dryer
5
Air-imp. dryer
6
7
Cylinder dryer
8
9
Upwinder
Speed
10
Moisture

Fig. 1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Div. of moist. diff. per unit 0-100 %
Model sp.ev.comp.
Coater station
IR dryer
Air-imp. dryer
Air-imp. dryer
Air-imp. dryer
Cylinder dryer
Moisture
Speed
Upwinder
Station N
Station N-1
1
2
3
4
5
6
8
9
10
12
1'
2'
3'
4'
5'
6'

Fig. 2

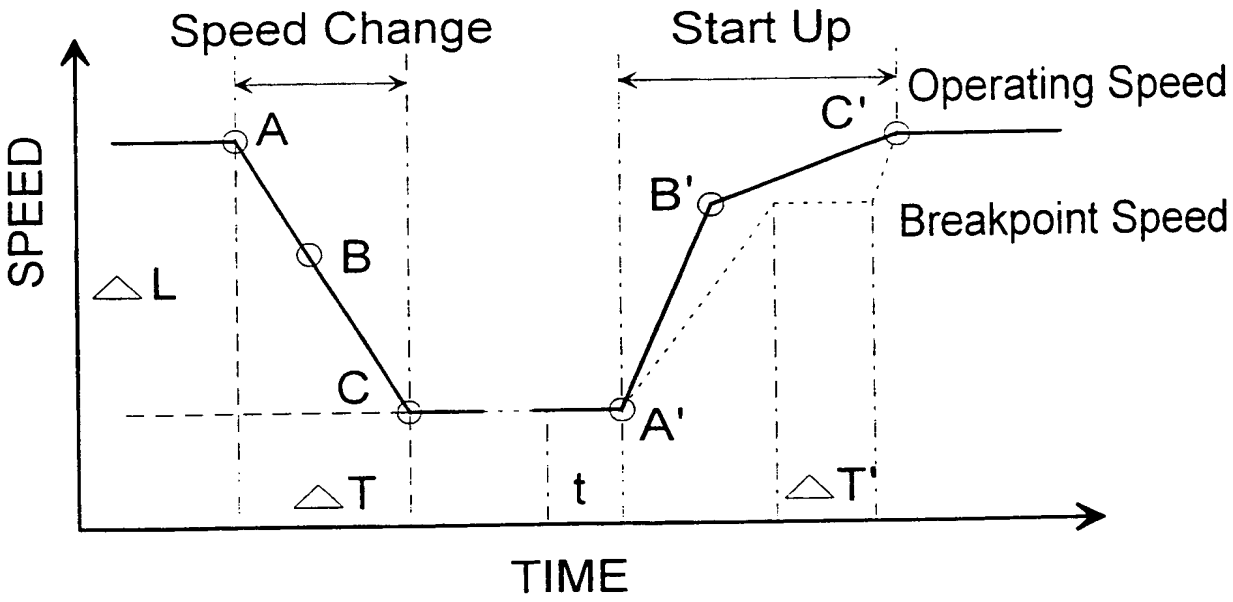
Speed Change
Start Up
Operating Speed
Breakpoint Speed
SPEED
TIME
A
B
C
A'
B'
C'
△L
△T
t
△T'

Fig. 3

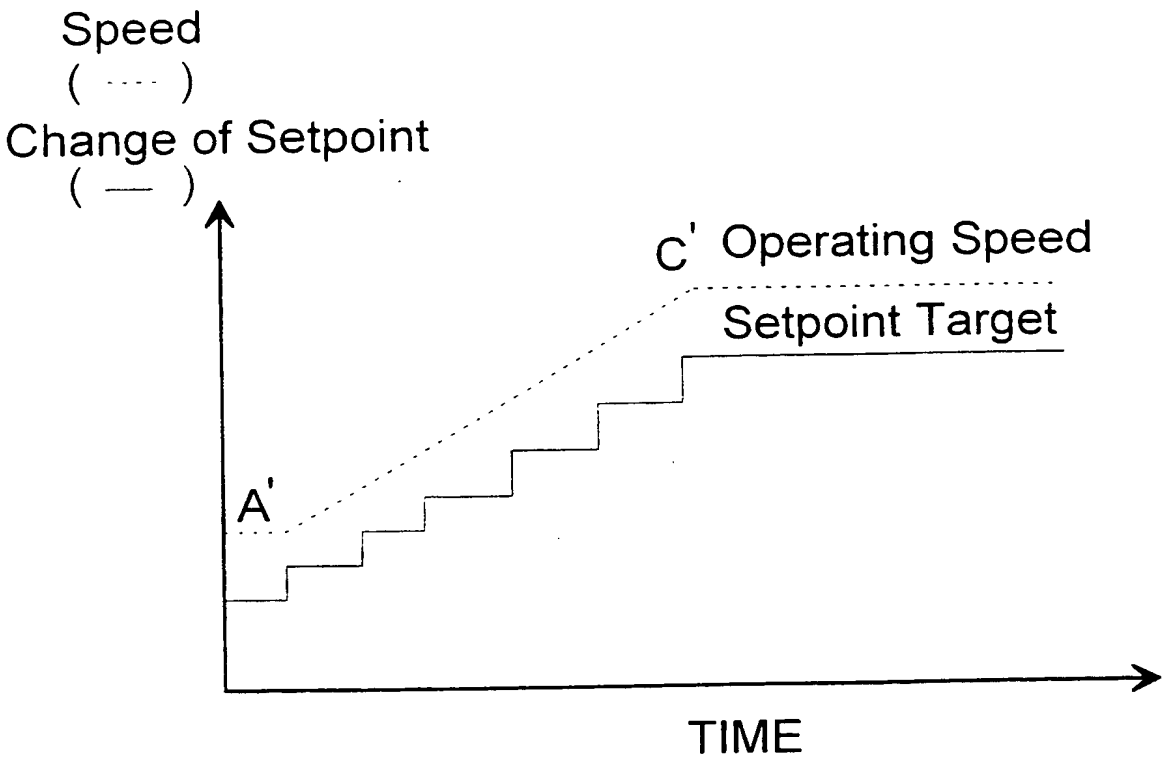
Speed
(····)
Change of Setpoint
(—)
C' Operating Speed
Setpoint Target
A'
TIME

Fig. 4

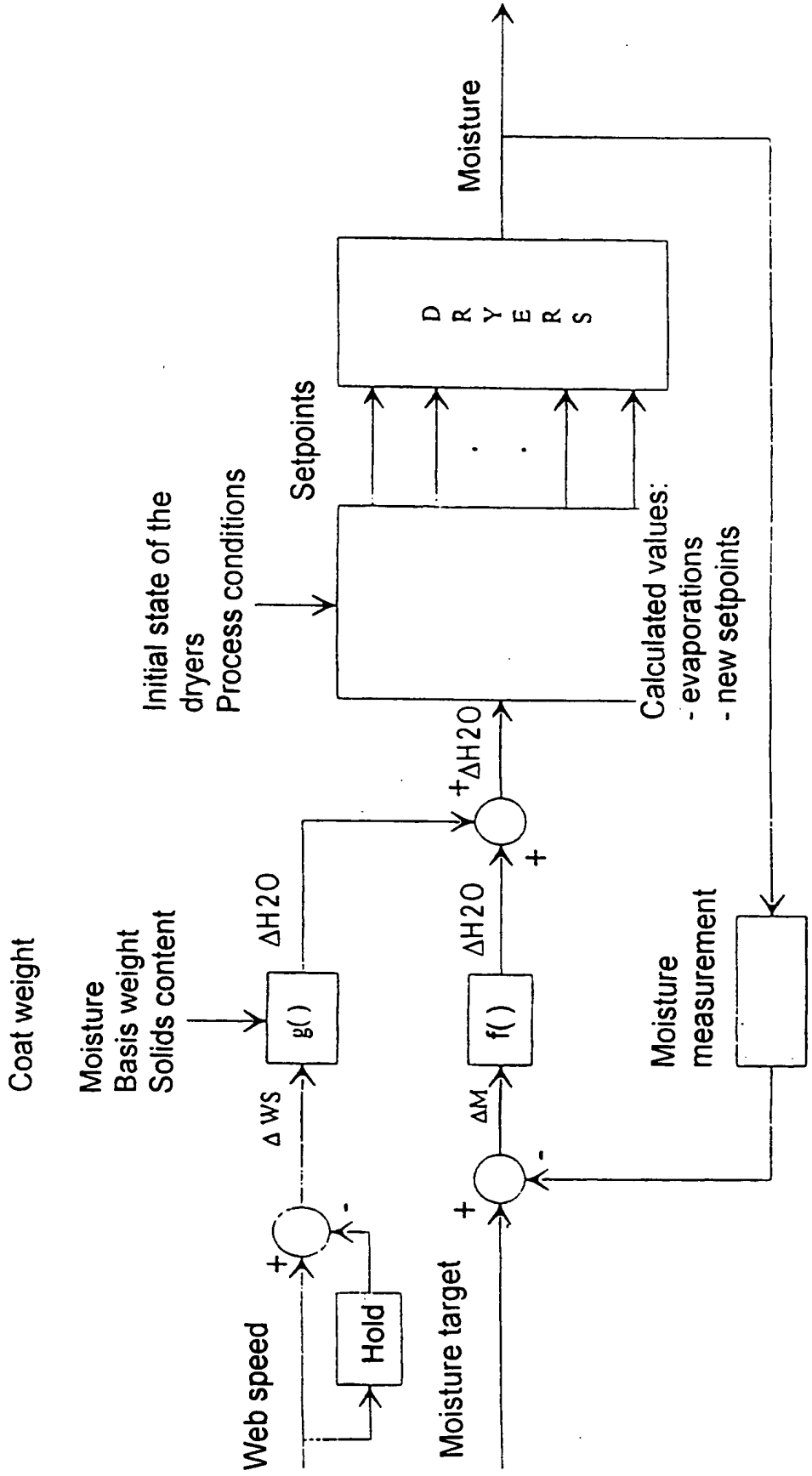
Moisture
D R Y E R S
Setpoints
Initial state of the dryers
Process conditions
Calculated values:
- evaporations
- new setpoints
+ΔH2O
ΔH2O
ΔH2O
g( )
f( )
Coat weight
Moisture
Basis weight
Solids content
Δ WS
ΔM
Moisture measurement
Web speed
Hold
Moisture target
+
-
+
-
+
+

FIG. 5